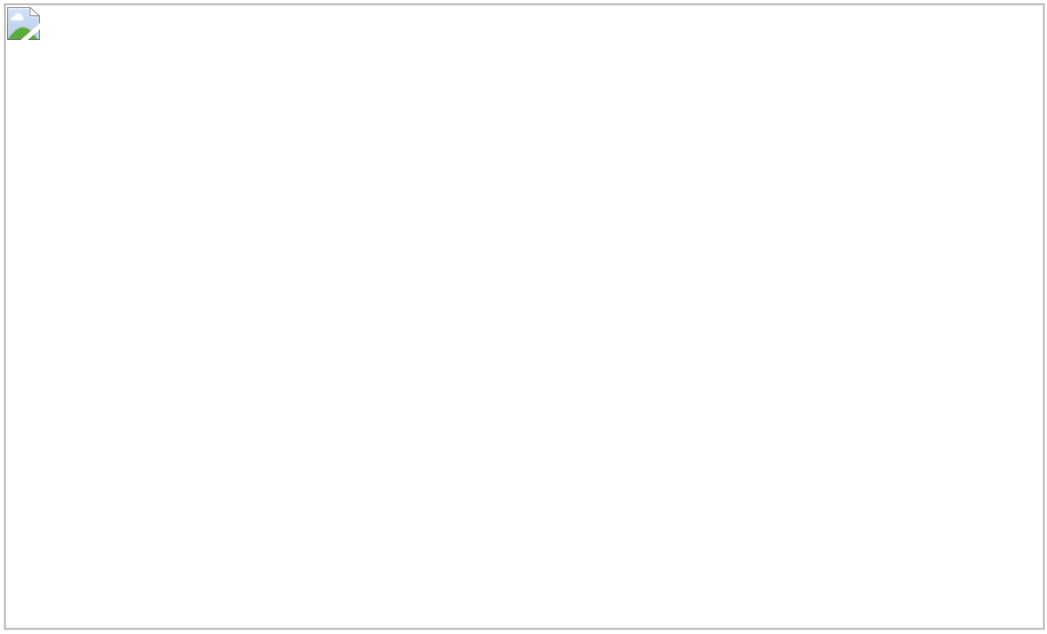
WORLD CLIMATE RESEARCH PROGRAMME (WCRP)

INTERNATIONAL GEWEX PROJECT OFFICE (IGPO)

TACTICAL DATA COLLECTION AND MANAGEMENT REPORT for the 1995 ENHANCED SEASONAL OBSERVING PERIOD (ESOP-95)



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TACTICAL DATA COLLECTION AND MANAGEMENT REPORT for the 1995

ENHANCED SEASONAL OBSERVING PERIOD (ESOP-95)

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PREFACE

The Enhanced Seasonal Observing Period of 1995 (ESOP-95) was conducted from 1 April 1995 to 30 September 1995 to provide the data support for the warm season focused studies in the Arkansas-Red River basin and to concentrate the GCIP buildup prior to the start of the five-year Enhanced Observing Period (EOP) on 1 October 1995.

We are particularly grateful to Steve Williams and his associates at the University Corporation for Atmospheric Research (UCAR) for the outstanding manner in which they coordinated the data collection efforts for ESOP-95 with two other field experiments supported by the UCAR Joint Office for Science Support (JOSS; formerly the Office of Field Project Support [OFPS]) during the same period. The Verifications of the Origins of Rotation in Tornadoes Experiment (VORTEX) was conducted from 1 April through 15 June 1995 in the same geographical area as ESOP-95 and the United States (US) Weather Research Program was conducting the STORM Weather-data Assimilation and Verification Experiment (STORM-WAVE) in the central United States from 1 April through 15 June 1995 over a larger geographical region.

By combining the data collection from ESOP-95 and VORTEX, researchers are provided with access to both routine operational as well as high-resolution augmented research network data. The STORM-WAVE focused on constructing a unique high resolution research-quality data set from national, regional, and state data sources for model verification and sensitivity studies during a critical part of the hydrologic water year. In addition, this data set was helpful in evaluating the data from the National Weather Service modernization program over a geographical domain similar to the GCIP Continental Scale Area and includes many of the same data sources that are being collected during the GCIP EOP.

This report completes the work started by GCIP in the spring of 1993 to compile a selected group of initial data sets needed by GCIP investigators prior to the start of the five-year EOP. In turn, the contribution by all the members of the GCIP Data Collection and Management (DACOM) committee during this three year effort has established a distributed infrastructure for the GCIP Data Management and Service System to provide data support to GCIP investigators for the duration of the Project.

John A. Leese, Chairman
DACOM

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1. INTRODUCTION

The Global Energy and Water Cycle Experiment (GEWEX), as one of the major programs of the World Climate Research Programme (WCRP), aims to determine global distributions of water and energy fluxes from observations and to compute their values from predicted atmospheric properties. The GEWEX Continental-scale International Project (GCIP), the first major project under GEWEX, has the Mississippi River basin as its primary region of interest.

1.1 The GCIP Project

The overall objectives of the GCIP are to improve scientific understanding of, and to model on a continental scale, the coupling between the atmosphere and the land surface for climate prediction purposes. This includes the determination of the temporal and spatial variability of the hydrological and energy budgets on the continental scale as well as the development and validation of macroscale hydrological models, related high resolution atmospheric models, and coupled hydrologic and atmospheric models. The operational or Enhanced Observing Period (EOP) of GCIP commenced in October 1995 and will run for approximately five years.

The GCIP Science Plan [World Meteorological Organization (WMO) 1992] poses science questions that need to be addressed to advance knowledge of the hydrological and energy cycles involved in the complex land-atmosphere-ocean interactions for a major river basin. The GCIP research involves a systematic multiscale approach to accommodate physical process studies, model development, data assimilation, diagnostics, and validation topics [International GEWEX Project Office (IGPO) 1994a)] This multiscale research effort employs a four-tiered developmental studies framework laid out as follows:

Continental-Scale Area (CSA) activities span the entire domain of the Mississippi River basin (3.2×10^6 km^2). These operate at a more or less steady level throughout the EOP.

Large-Scale Area (LSA) activities cover areas of about $10^5$to 10^6km^2. Four such areas were defined for GCIP that in aggregate cover most of the GCIP domain (Figure 1-1). These activities occur in a phased timetable (Figure 1-1), examining each regions special characteristics over a two year period.

Intermediate-Scale Area (ISA) activities cover areas of about 10^3 to 10^4 km^2 and occur in conjunction with LSA activities. They serve as the basis for the regionalization of the parameters and coefficients of land surface hydrological models. Activities at ISA scales include the analysis of existing basin-scale hydrological models and the analysis of relationships between LSA and ISA scales.

Small-Scale Area (SSA) activities cover areas of about 10^2 km^2. These activities typically occur in association with efforts requiring Intensive Observing Periods (IOPs) over concentrated regions to study a focused set of issues.

The data collection and operational model upgrades needed for GCIP were addressed in Volume I of the GCIP Implementation Plan (IGPO 1993). The issues of data management for GCIP are divided into strategic and tactical planning efforts. The strategic portion of the data management planning was covered in Volume III of the GCIP Implementation Plan (IGPO 1994b). A tactical data collection and management plan will be completed for each definable data set compiled by GCIP. Following the data collection phase of each definable GCIP data set, a tactical data collection and management report will be completed.

1.2 GCIP Initial Data Sets

A number of GCIP Initial Data Sets (GIDS) were prepared to provide data services support during the 2-yr buildup period prior to the start of the 5-yr EOP in October 1995. GIDS-1 covered the period from 1 February to 30 April 1992 and included data from the STorm-scale Operational and Research Meteorology (STORM)-Fronts Experiment Systems Test (FEST) augmented by an additional six weeks of atmospheric, hydrological, and land surface data from existing data centers for the central Mississippi River basin. GIDS-2 is planned to consist of two abnormal climate events in the Mississippi River basin, i.e. the 1988 drought and the 1993 floods. GIDS-3 consists of data collected during the GCIP Integrated Systems Test (GIST) which took place from 1 April to 31 August 1994, with a concentrated effort during the summer season of June, July, and August. The GIST took place in the LSA-SW (see Figure 1-1). The final GIDS data set is GIDS-4 which consists of data collected during the 1995 Enhanced Seasonal Observing Period (ESOP-95) (1 April to 30 September 1995) which is the subject of this document. A GCIP Reference Data Set (GREDS) was completed in early 1995. The 17 different data sets on this CD-ROM contain data that are expected to change little if any during the next two to three years. A summary of the contents of each of the above data sets is given in the GCIP Major Activities Plan for 1995, 1996 and Outlook for 1997 (IGPO 1995). Specific information about each data set is available on the Internet World Wide Web (WWW) via the GCIP home page at the following URL (Uniform Resource Locator):

http://www.ogp.noaa.gov/gcip/

1.3 1995 Enhanced Seasonal Observing Period (ESOP-95)

The ESOP-95 was conducted from 1 April through 30 September 1995 and continued the ongoing program of observations in support of the LSA-SW focus from 1994 through 1996 as was shown in Figure 1-1. A major objective for ESOP-95 was to contribute to a comprehensive data set for diagnostic, evaluation, and modeling studies. There were no GCIP IOPs conducted during the ESOP-95 period. The LSA-SW has four environmental features that are significant to GCIP: A large east-west variation in climate, a large water vapor transfer via a low level jet, a large portion of the precipitation is due to convective activity, and there is a large diurnal variability in the summer season for hydrologic components such as water vapor transport and convective regimes. The scientific objectives and approach for these studies are described in the GCIP Major Activities Plan for 1995, 1996 and Outlook for 1997 (IGPO 1995).

The GCIP LSA-SW domain is shown in Figure 1-2. The geographical area of responsibility for the National Oceanic and Atmospheric Administration (NOAA)-National Weather Service (NWS) Arkansas-Red Basin River Forecast Center (ABRFC) in Tulsa, Oklahoma, was used to define the areas of the Arkansas-Red River basins as the irregular shaped polygon in Figure 1-2. For atmospheric modeling and other applications a more regular-shaped area was defined by the boundaries of 33^o to 40^o N latitude and 91^o to 107^o W longitude, and these were used as the latitude-longitude boundaries for the LSA-SW. The meteorological and hydrological networks covering the Mississippi River basin were being enhanced by new Weather Surveillance Radar - 1988 Doppler (WSR-88D) radars, wind profilers, and automatic weather stations. Most of these systems were already operating in the LSA-SW. Enhancements to these observing networks were also available in the form of mesoscale networks, the Department of Energy (DOE) Atmospheric Radiation Measurements (ARM) Program at the

Southern Great Plains (SGP) Cloud and Radiation Testbed (CART) facility, and the Verification of the Origins of Rotation in Tornadoes Experiment (VORTEX). Further data were collected as a part of the STORM-Weather-data Assimilation and Verification Experiment (WAVE). The linkages between ESOP-95, ARM/CART, VORTEX, and STORM-WAVE are discussed in Section 2.

1.4 Purposes of Document

This document is entitled the Tactical Data Collection and Management Report for ESOP-95 and is intended to serve a dual purpose:

(i) A summary of the data collection efforts that occurred during the period of 1 April through 30 September 1995. Some of the specialized efforts for enhanced observations (i.e. ARM/CART and VORTEX described in Section 2) have operations plans which were prepared by the persons contributing those enhanced observations to the ESOP-95.

(ii) The data collected during ESOP-95 provided the basis for the fourth initial data set (GIDS-4). This document summarizes the data sets that were developed for ESOP-95.

The approach to ESOP-95, a description of the data collected, and how it is being disseminated are described in the remainder of this document.

2. OBJECTIVES AND APPROACH

The purpose of compiling the ESOP-95 data set was to create a prototype data set over one of the GCIP LSAs that was similar to the future data sets collected during the GCIP EOP which began in October 1995, and enables GCIP investigators to conduct focused studies (i.e. coupled model and diagnostic) unique to the LSA-SW during the summer season. The research objectives to be achieved from the ESOP-95 data sets are described in the GCIP Major Activities Plan (IGPO 1995). The approach taken by the GCIP was to rely on existing operational observing programs over the continental United States while taking advantage of special collection of higher resolution data. Also, as additional improvements were made to the operational observing systems [i.e. Automated Surface Observing System (ASOS) and WSR 88-D] they were incorporated. These operational networks included the traditional meteorological and hydrological networks in addition to WSR-88D radars, wind profilers, ASOS, satellites, and operational model output. The LSA-SW was selected in part because many of these additional systems were already available. Also, within the LSA-SW, there were the enhanced special observational networks associated with the ARM/CART and VORTEX projects. Also, operational data outside of the LSA-SW were collected for the STORM-WAVE project.

The primary objective of the ARM program is to characterize the radiative processes in the earth's atmosphere with improved accuracy and resolution (Stokes and Schwartz 1994). The strategy is to deploy, for at least a decade, a sufficiently complete set of observing systems that, when combined with other operational or experimental systems, will obtain a continuous representation of the radiative and meteorological fields over a volume of space equivalent to the minimum spatial resolution of a typical global climate model (GCM). The goal of CART is to generate a data set that is sufficiently complete to enable diagnosis of the performance of GCM subgrid scale paramiterization schemes that are important to representing cloud and radiation properties in these models.

The sensor systems and measurements at the ARM/CART site (Figure 1-2) were described in Volume I of the GCIP Implementation Plan (IGPO 1993). Information on the instrumentation in place during the ESOP-95 period can be found in Schneider, et al. (1994) and Splitt, et al. (1995). Commonality of research interests between GCIP, ARM, and ISLSCP (International Satellite Land-Surface Climatology Project) form the basis for unique observational and data analysis opportunities within the ARM/CART site. From the GCIP perspective, the ARM/CART site is large enough (almost 10^5 km^2) and is well enough instrumented for approximate closure of the atmospheric energy and water budgets. The size of the ARM/CART area places it between the LSA and

ISA ranges. Therefore, some LSA studies can be done over the ARM/CART area as well as over the entire LSA-SW.

Within the ARM/CART site, the opportunities to conduct ISA studies are numerous. At the ISA scale, precipitation and streamflow can be measured accurately and, although it is not possible to measure areal average evapotranspiration and soil moisture, extensive in situ surface measurements related to evapotranspiration or soil moisture will be made as part of ARM, ISLSCP, the Oklahoma Mesonet, NOAA/NWS observations, and other programs. The ARM/CART site also includes a range of climate, soils, and vegetation regimes and is therefore an attractive location for the development and validation of remote sensing algorithms.

The ARM program in addition to its continuous observational base often conducts periods of more intensive data collection. These IOPs are conducted for observations that are too expensive for continuous operation or require instrumentation that cannot be continuously deployed. IOPs are also used to examine issues of data quality or representativeness through intercomparisons. During the ESOP-95 period, ARM conducted several IOPs.

Seasonal Single-Column Model (SCM) IOPs were conducted in April, July, and September 1995. An SCM is a physical parameterization package extracted from a GCM. The primary purpose of the SCM IOPs was to test the current understanding of clouds and radiative transfer. These SCM IOPs provide, as boundary conditions, the advective tendencies and vertical velocities that are the dynamic forcing normally calculated with a GCM. The balloon-borne sounding system is the only technology able to provide the necessary observations to estimate these boundary conditions. Thus, these IOPs included an enhanced frequency of vertical soundings of temperature, water vapor and winds, as well as other observations. The sounding frequency was increased to eight per day at the central and boundary facilities (see Figure 3-15). These SCM IOPs also served as useful background data collection efforts for simultaneous IOPs.

During April and May 1995 the Remote Cloud Sensing Field Evaluation IOP occurred. The primary purpose was to conduct a field evaluation and calibration of several remote sensing cloud-observing instruments. Included among the remote sensors operational during this IOP were Raman lidars [National Aeronautics and Space Administration (NASA)/Goddard Space Flight Center (GSFC) and Sandia National Laboratories], 95 GHz radar and Polarization Diversity Lidar (University of Utah), a Doppler lidar (NOAA/Environmental Technology Laboratory), an infrared radiometer [Commonwealth Scientific and Industrial Research Organisation (CSIRO)], a combined 35/95 GHz and another 95 GHz mm-wave radar (University of Massachusetts), a 95 GHz radar [Pennsylvania State University (PSU)], a combined narrow-field-of-view/hemispherical-field-of-view infrared radiometer (NASA/Ames Research Center), and a sky-scanning spectrophotometer (NASA/GSFC). Additional already tested and operational sensors included the AERI (Atmospherically Emitted Radiance Interferometer) (University of Wisconsin), SORTI (Solar Radiance Transmission Interferometer) (University of Denver), and the Micropulse Lidar (NASA/GSFC). Flight operations were conducted by the University of North Dakota Citation aircraft.

Also during April and May 1995 the Simultaneous Ground-Based, Airborne, and Satellite-borne Microwave Radiometric and In-Situ Observations of Cloud Optical Properties and Surface Emissivities IOP occurred. The objectives of this IOP were threefold. First, to augment time series from ground-based sensors required to test inhomogeneous cloud models by acquiring observations of cloud liquid water path, liquid water content, in-cloud extinction, effective droplet radius, and shortwave radiation over a typical GCM cell surrounding the central facility. Second, to more accurately quantify the capabilities of the remote sensors using observations simultaneously obtained from ground-based, satellite-borne, and in-situ sensors. Finally, to measure the spatial variability of the surface emissivity at microwave frequencies of the ARM/CART site with sufficient accuracy to permit the routine retrieval of total precipitable vapor and cloud liquid water path from SSM/I (Special Sensor Microwave Imager). This included NOAA P-3 aircraft flights to examine stratocumulus clouds.

Also during April and May 1995 the VORTEX-ARM IOP took place. The focus of this IOP was a joint VORTEX-ARM proposal for the NOAA P-3 aircraft study of stratocumulus clouds.

During June and July 1995 the Surface Energy Exchange IOP occurred. The primary purpose of this IOP was to relate variations of the Planetary Boundary Layer (PBL) structure to the underlying surface fluxes through

detailed observations of temperature and moisture profiles in the PBL within 75-125 km of the central facility by using airsondes and profilers.

Also during June and July 1995 the Sampling of Coherent Structures with the 915 MHz Profiler IOP occurred. Coherent structures in the convectively unstable boundary layer are a primary source of energy transport between the surface layer and the free troposphere. Routine profiler operation samples these plumes for only about 30 s every 2.5 min. To resolve coherent structures, sampling was increased to about every 15 s and this was accomplished by running in the vertical only mode during the afternoon period.

Finally, during the last half of September (and continuing into October) 1995 the ARM Enhanced Shortwave Experiment (ARESE) took place (Valero, et al. 1997). This IOP addressed the phenomenon of unexplained anomalous absorption of solar radiation by clouds. This IOP obtained measurements of short and long wave radiative fluxes from ground-based, unmanned aerospace vehicles, and other platforms, as well as satellite systems. These data were used to quantify the redistribution of energy from the surface into the atmosphere and how that energy forces the climate system. In conjunction with this IOP there was also the fall 1995 ARM Unmanned Aerial Vehicle IOP.

The ESOP-95 was coordinated with the VORTEX project which was conducted from 1 April through 15 June 1995 in the Arkansas-Red River Basin area (Figure 1-2). The broad objectives of VORTEX were to gain understanding of tornadogenesis processes, the roles of the environment in producing and modulating tornadic storms, and tornado kinematics and dynamics (Rasmussen et al. 1994). Many of the same observations required to support VORTEX objectives were also useful for GCIP thus providing a natural collaboration of the projects. In fact, by combining the data collection from VORTEX and ESOP-95, researchers are provided with access to both routine operational as well as high-resolution augmented research network data.

The ESOP-95 was also coordinated with the STORM-WAVE that was executed by the United States Weather Research Program (USWRP) in the central United States from 1 April through 15 June 1995. This effort focused on constructing a unique high resolution research-quality data set from national, regional, and state data sources for model verification and sensitivity studies during a critical part of the hydrologic water year. In addition, this data set was to help evaluate data from the NWS modernization program. Such a data set is important to GCIP, because the STORM-WAVE domain (Figure 2-1) is similar to the GCIP CSA (including the LSA-SW) and includes many of the same data sources that are being collected in the GCIP EOP.

In summary, ARM/CART, VORTEX, and STORM-WAVE, in conjunction with ESOP-95, provide a data set that: (1) includes atmospheric and hydrological data obtained in a major river basin; (2) includes a hydrologically important time of year (i.e. early spring through summer); (3) includes routine operational data as well as special research observing platforms combined for a six month period; and (4) provides similar quality controlled surface and upper air composite data sets as required by the GCIP EOP.

3. DATA SOURCES AND DATA COLLECTION

The ESOP-95 data can be divided into three major data categories: In situ, satellite, and model. Although most of the data sources were operational in nature, special arrangements were made to obtain these data in the highest resolution possible. Table 3-1 summarizes the individual data sets comprising the ESOP-95. A brief description of each data set is then provided in the following subsections with information regarding data collection, processing, and final archival. Acronyms within the table are defined within each data set summary section as well as in Appendix A. Information on data set dissemination is provided in Section 5.

TABLE 3-1 Data sets comprising the ESOP-95

IN-SITU DATA

Surface Data

Automated Surface Observing System (ASOS) Data
Automated Weather Observing System (AWOS) Data
Surface Airways Observations (SAO) Hourly Data
SAO Special Observation Data
High Plains Climate Network (HPCN) Data
Oklahoma Mesonet Data
Colorado Agricultural Meteorology (CoAgMet) Network Data
NOAA Profiler Network (NPN) Surface Observations
DOE ARM/CART Surface Data
NOAA/NWS Cooperative Observer Daily Observations
NOAA/NWS Cooperative Observer Precipitation Data
ABRFC Precipitation Data
USGS Streamflow Data
USGS Reservoir Data
Cooperative Agency Reservoir Data
ESOP-95 Hourly Surface Composite
ESOP-95 20-minute Surface Composite
ESOP-95 5-minute Surface Composite
ESOP-95 Hourly Precipitation Composite
ESOP-95 15-minute Precipitation Composite
ESOP-95 Daily Precipitation Composite

Upper Air Data

NWS Upper Air Rawinsonde Data (6-sec vertical levels)
NWS Upper Air Rawinsonde Data (mandatory/significant levels)
DOE ARM/CART Site Upper Air Data
VORTEX Fixed and Mobile Site Upper Air Data
NOAA Profiler Network (NPN) Data

Radar Data

WSR-88D Data
WSR-88D NIDS Data
WSI Reflectivity Composite Imagery
ABRFC Stage III WSR-88D Data
NASA/MSFC National Radar-derived Precipitation Rate Composite

Land Characterization Data

Little Washita River Basin Soils and Land Cover
PSU 1-km Multi-Layer Soil Characteristics Data Set

SATELLITE DATA

GOES-7/8 Satellite Imagery (IR, VIS, and 6.7 micron)
GOES-7/8 VAS Data/Derived Products
NOAA POES AVHRR Imagery
NOAA POES TOVS Data
DMSP SSM/I Data/Imagery
NOAA Weekly Northern Hemisphere Snow Cover Analysis
GOES/ASOS Cloud Observations
CLAVR Clouds
Satellite Radiation Data Sets
EDC Bi-Weekly Vegetation Index Data

MODEL OUTPUT

Atmospheric Model Output

NOAA/NCEP Eta Model Output
NOAA/NCEP Eta Model Initial Analysis Daily GIFs
NOAA/NCEP Eta Model Location Time Series (MOLTS)
Eta MOLTS Derived Sounding Output
AES/CMC RFE Model Output
MORDS Output
NOAA/FSL MAPS Model Output

Hydrological Model Output

ABRFC Hydrologic Model Output

3.1 In-Situ Data

The following in-situ data sets were collected, processed, quality assured, archived, and disseminated at the In-Situ Data Source Module at the University Corporation for Atmospheric Research (UCAR)/Joint Office for Science Support (JOSS; formerly the Office of Field Project Support [OFPS]). Data set details are provided in the following subsections. Included is the information on the name under which each data set can be found on the UCAR/JOSS CODIAC data management system (see Section 5.1.1). Information on data and metadata retrieval is provided in Section 5.

3.1.1 Surface Data

Automated Surface Observing System (ASOS) Data - These data include 5-minute observations of temperature, dew point, station pressure, precipitation type (rain, snow, and freezing rain), precipitation amount, wind speed, wind direction, visibility to 10 miles, and sky condition to 12,000 feet. These data were available at 66 uncommissioned and 16 commissioned sites within the LSA-SW (Figure 3-1). The 5-minute and hourly ASOS data were routinely downloaded over telephone modem on a daily basis by JOSS. The 5-minute and hourly data were converted to a common ASCII surface format, merged, quality controlled, and archived at JOSS as a part of the GCIP/ESOP-95 5-minute and Hourly Surface Composites. The precipitation data were extracted from the 5-minute (Hourly) Surface Composite and converted to 15-min (Daily) values which were converted to a common ASCII precipitation format, merged, quality controlled, and archived at JOSS as a part of the 15-minute (Daily) Precipitation Composite. The hourly precipitation data were also extracted from the Hourly Surface Composite, converted to a common ASCII precipitation format, merged, quality controlled, and archived at JOSS as a part of the Hourly Precipitation Composite. Commissioning means that the ASOS station has passed all operational and quality assurance specifications and replaces the manual observations with 24-hour automated observations at that station. **NOTE - Caution should be exercised by the researcher when using uncommissioned ASOS data**.

Automated Weather Observing System (AWOS) Data - This includes both Federal (i.e. Federal Aviation Administration [FAA]) and non-Federal (i.e. state aviation agencies or local airports) AWOS sites. It includes 20-minute (except one site in Norman, Oklahoma which has 5-minute) observations of temperature, dew point, station pressure, precipitation type (rain, snow, and freezing rain), precipitation amount, wind speed, wind direction, visibility to 10 miles, and sky condition to 12,000 feet. These data were available at 33 sites within the LSA-SW (Figure 3-2). The 20-minute (and 5-minute for the one station) AWOS data were routinely downloaded over telephone modem on a daily basis by JOSS. The 20-minute (5-minute) data were converted to a common ASCII surface format, merged, quality controlled, and archived at JOSS as part of the GCIP/ESOP-95 20-minute (5-minute) Surface Composite. The 20-minute observations were also processed into hourly observations, converted to a common ASCII surface format, merged, quality controlled, and archived at JOSS as a part of the GCIP/ESOP-95 Hourly Surface Composite. The precipitation data were also extracted, converted to a common ASCII precipitation format, merged, quality controlled, and archived at JOSS as a part of the GCIP/ESOP-95 15-minute (in the case of the one 5-minute station), Hourly, and Daily Precipitation Composites.

Surface Airways Observations (SAO) Hourly Data - These data include hourly SAOs of temperature, dew point, station and sea level pressure, altimeter setting, precipitation type and amount, wind speed, wind direction, visibility, ceiling, and cloud type, height, and amount, and remarks. Data were routinely recorded at 97 sites

within the LSA-SW (Figure 3-3) and were processed and archived at the National Climatic Data Center (NCDC). Data for the ESOP-95 period were extracted and forwarded to the JOSS. These hourly observations were converted to a common ASCII surface format, merged, quality controlled, and archived at JOSS as a part of the GCIP/ESOP-95 Hourly Surface Composite. The precipitation data were also extracted, converted to a common ASCII precipitation format, merged, quality controlled, and archived at JOSS as a part of the GCIP/ESOP-95 Hourly and Daily Precipitation Composites.

SAO Special Observation Data - These data include the "special" SAOs. These are SAOs that are reported at off-hour times and report significant changes in conditions from the previous hourly reports. These reports can include all of the information shown above for the hourly SAOs, but more typically, report only portions of the data. A complete listing of the requirements to issue a "special SAO" are included in the Federal Meteorological Handbook No. 1 (1988). Data were routinely recorded at up to 97 sites within the LSA-SW (see Figure 3-3) and were processed and archived at NCDC. Data for the ESOP-95 period were extracted and forwarded to the JOSS. These data are not included as part of any composite data set and were not quality controlled by JOSS. These data are available from JOSS as the GCIP/ESOP-95 NCDC SAO Specials Data Set.

High Plains Climate Network (HPCN) Data - The HPCN mesonet routinely collected and archived hourly observations of temperature, dew point, precipitation amount, wind speed, and wind direction to support agricultural operations on the high plains. These data were available from 18 sites in the LSA-SW (Figure 3-4). The data were collected, processed, and archived by the High Plains Climate Center at the University of Nebraska/Lincoln. Data for the ESOP-95 period were extracted and forwarded to the JOSS. The hourly data were converted to a common ASCII surface format, merged, quality controlled, and archived at JOSS as a part of the GCIP/ESOP-95 Hourly Surface Composite. The precipitation data were also extracted, converted to a common ASCII precipitation format, merged, quality controlled, and archived at JOSS as a part of the GCIP/ESOP-95 Hourly and Daily Precipitation Composites.

Oklahoma Mesonet Data - The Oklahoma Mesonet sites routinely collected and archived 5-minute observations of temperature, relative humidity, station pressure, precipitation amount, wind speed, wind direction, and solar radiation. These data were available from 111 sites (at least one per Oklahoma county) in the LSA-SW (Figure 3-5). The data were collected, processed, and archived by the Oklahoma Climate Survey at the University of Oklahoma. Data for the ESOP-95 period were extracted and forwarded to the JOSS. The 5-minute data were converted to a common ASCII surface format, merged, quality controlled, and archived at JOSS as a part of the GCIP/ESOP-95 5-minute Surface Composite. The 5-minute observations were also processed into hourly observations which were converted to a common ASCII surface format, merged, quality controlled, and archived at JOSS as a part of the GCIP/ESOP-95 Hourly Surface Composite. The precipitation data were also extracted, converted to a common ASCII precipitation format, merged, quality controlled, and archived at JOSS as a part of the GCIP/ESOP-95 15-minute, Hourly, and Daily Precipitation Composites.

Colorado Agricultural Meteorology (CoAgMet) Network Data - The Colorado Climate Center routinely collected hourly observations of temperature, relative humidity, wind speed, wind direction, and precipitation. These data were available from seven sites within LSA-SW (Figure 3-6). These data were from a variety of local agricultural networks and were archived by the Colorado Climate Center at Colorado State University. Data for the ESOP-95 period were extracted by JOSS via the Colorado Climate Center WWW home page. The hourly data were converted to a common ASCII surface format, merged, quality controlled, and archived at JOSS as a part of the GCIP/ESOP-95 Hourly Surface Composite. The precipitation data were also extracted, converted to a common ASCII precipitation format, merged, quality controlled, and archived at JOSS as a part of the GCIP/ESOP-95 Hourly and Daily Precipitation Composites.

NOAA Profiler Network (NPN) Surface Observations - The NOAA NPN (formerly the NOAA Wind Profiler Demonstration Network [WPDN]) routinely recorded hourly surface observations of temperature, dew point, station pressure, precipitation amount, wind speed, and wind direction at 13 of its 16 profiler sites in the LSA-SW (Figure 3-7). The data were routinely collected and processed by NOAA/Forecast Systems Laboratory (FSL) and archived at NOAA/NCDC. Data for the ESOP-95 period were extracted and forwarded to the JOSS. The hourly data were converted to a common ASCII surface format, merged, quality controlled, and archived at JOSS as a part of the GCIP/ESOP-95 Hourly Surface Composite. The precipitation data were also extracted,

converted to a common ASCII precipitation format, merged, quality controlled, and archived at JOSS as a part of the GCIP/ESOP-95 Hourly and Daily Precipitation Composites.

DOE ARM/CART Surface Data - The DOE ARM Program routinely obtained 1-minute surface measurements from its Surface Meteorological Observation Stations (SMOS) at the Southern Great Plains (SGP) CART site in Kansas and Oklahoma. These measurements include wind, temperature, humidity, and clouds at 10 sites in the LSA-SW (Figure 3-8). The data were collected and processed by the DOE ARM Program and archived at DOE Oak Ridge National Laboratory (ORNL). Data for the ESOP-95 period were extracted and forwarded to the JOSS. The 1-minute data were converted to 5-minute and hourly observations which were converted to a common format ASCII surface format, merged, quality controlled, and archived at JOSS as a part of the GCIP/ESOP-95 5-minute and Hourly Surface Composites. The precipitation data were also extracted, converted to a common ASCII precipitation format, merged, quality controlled, and archived at JOSS as a part of the GCIP/ESOP-95 15-minute, Hourly, and Daily Precipitation Composites.

NOAA/NWS Cooperative Observer Daily Observations - The NOAA/NWS routinely recorded daily observation of maximum and minimum temperature, precipitation, snowfall, and snow depth. These sites were operated by cooperative observers over the conterminous US and were processed and archived by NOAA/NCDC. Data for the 1406 stations within the LSA-SW (Figure 3-9) were extracted and forwarded to the JOSS. The precipitation data were extracted, converted to a common ASCII precipitation format, merged, quality controlled, and archived a JOSS as a part of the GCIP/ESOP-95 Daily Precipitation Composite. The full data set (which did not undergo any quality control by JOSS) is available from JOSS and NCDC as the NCDC Summary of the Day Cooperative Data Set.

NOAA/NWS Cooperative Observer Precipitation Data - The NOAA/NWS routinely collected 15-minute (426 sites) or hourly (26 sites) observations of precipitation from Fisher-Porter and Universal rain gages operated by cooperative observers in the LSA-SW (Figure 3-10). These data were processed and archived by NOAA/NCDC. Data for the ESOP-95 period were extracted and forwarded to the JOSS. These data were converted to a common ASCII precipitation format, merged, quality controlled, and archived at JOSS as a part of the GCIP/ESOP-95 15-minute, Hourly, and Daily Precipitation Composites.

ABRFC Precipitation Data - These data include precipitation observations from 1365 stations within the ABRFC region of responsibility (see Figure 1-2) and from a variety of source agencies, including the US Army Corps of Engineers (USACE). The frequency of the observations varied from 15 min (166 stations) to hourly (239 stations) to stations that collected data with no set schedule (960 stations). A map of the ABRFC precipitation stations is shown in Figure 3-11. These data were archived by the NOAA/Office of Hydrology (OH) in Silver Spring, MD. Data for the ESOP-95 period were extracted and forwarded to the JOSS. The 15-minute and hourly data were converted to a common ASCII precipitation format, merged, quality controlled, and archived at JOSS as a part of the GCIP/ESOP-95 15-minute, Hourly, and Daily Precipitation Composites. The full data set (which has undergone no quality control by JOSS), including those sites that reported with no set schedule, is available from JOSS as the ABRFC Miscellaneous Precipitation Data Set.

United States Geological Survey (USGS) Streamflow Data - These data include daily observations of precipitation and streamflow from USGS and USACE gages. A total of 983 streamflow stations (Figure 3-12) were located within the LSA-SW and all data are available through the USGS National Water Data Exchange (NAWDEX) Office in Reston, VA as well as the district (state) offices. Data for the ESOP-95 period were extracted and forwarded to the JOSS. These data have undergone no quality control by JOSS. These data are available from JOSS as the GCIP/ESOP-95 USGS Streamflow Data Set. *NOTE - The streamflow data were generally not adjusted for diversions or reservoir storage.*

USGS Reservoir Data - These data include daily observations of reservoir contents or water level for 97 reservoirs within the LSA-SW (Figure 3-13). All data are available through the USGS NAWDEX Office in Reston, VA as well as the USGS and USACE district offices. Data for ESOP-95 period were extracted and forwarded to the JOSS. These data have undergone no quality control by JOSS. These data are available from JOSS as the GCIP/ESOP-95 USGS Reservoir Data Set.

Cooperative Agency Reservoir Data - These data include monthly observations of reservoir contents or water level for 18 reservoirs within the LSA-SW (Figure 3-13). These data were collected and archived by the USGS and data for the ESOP-95 period were extracted and forwarded to JOSS. These data have undergone no quality control by JOSS. These data are available from JOSS as the GCIP/ESOP-95 Cooperative Agency Reservoir Data Set.

ESOP-95 Hourly Surface Composite - This composite contains station and sea level pressure, temperature, dew point, wind speed and direction, and precipitation hourly observations from surface observing sites in the LSA-SW as well as visibility, present weather, ceiling and cloud type heights and amounts for those stations that report them (generally SAO and ASOS). This composite does not contain the precipitation data from those sites that collected only precipitation data (i.e. the site must also have collected meteorological observations to have been included). The precipitation only sites were included within the precipitation composites which are described below. The composite was produced by the JOSS and contains hourly data from the following networks: ASOS, AWOS, SAO's, HPCN, Oklahoma Mesonet, CoAgMet, DOE ARM/CART, and NPN surface observations. These data were all converted to a common ASCII surface format, merged, and quality controlled (see Section 4.1.1) by JOSS.

ESOP-95 20-minute Surface Composite - Similar to the ESOP-95 Hourly Surface Composite (above) but only the 20-min data from the AWOS (excluding the one 5-minute station) surface stations were converted to a common ASCII surface format, merged, and quality controlled (see Section 4.1.1) to form this composite.

ESOP-95 5-minute Surface Composite - Similar to the ESOP-95 Hourly Surface Composite (above) but only the 5-min data from ASOS, Oklahoma Mesonet, the Norman, OK AWOS, and DOE ARM/CART surface stations were converted to a common ASCII surface format, merged and quality controlled (see Section 4.1.1) to form this composite.

ESOP-95 Hourly Precipitation Composite - This composite contains precipitation data from all real-time and recording gages in the LSA-SW. The composite was produced by the JOSS and contains hourly totals from gages in the following networks: ASOS, AWOS, SAO's, HPCN, Oklahoma Mesonet, CoAgMet, DOE ARM/CART, NPN, NWS Cooperative Observer, and ABRFC. These data were converted to a common ASCII precipitation format, merged, and quality controlled (see Section 4.1.2) by JOSS.

ESOP-95 15-minute Precipitation Composite -This composite was formed from data from four sources, the ABRFC 15-min precipitation data, NCDC 15-min precipitation data, Oklahoma Mesonet precipitation data, and the precipitation data extracted from the GCIP/ESOP-95 5-min Surface Composite. Data from these four sources were converted to a common ASCII precipitation format, merged, and quality controlled (see Section 4.1.2) by JOSS to form the composite.

ESOP-95 Daily Precipitation Composite - This composite contains precipitation data from all real-time and recording gages in the LSA-SW. The composite was produced by the JOSS and contains daily totals from gages in the following networks: ASOS, AWOS, SAO's, HPCN, Oklahoma Mesonet, CoAgMet, DOE ARM/CART, NWS Cooperative Observer, ABRFC, and NPN. These data were converted to a common ASCII precipitation format, merged, and quality controlled (see Section 4.1.2) by JOSS.

3.1.2 Upper Air Data

NWS Upper Air Rawinsonde Data (6-sec vertical levels) - This data set contains 12-hourly (occasionally more frequent at the request of VORTEX or the NWS) vertical profiles of time, pressure, temperature, altitude, relative humidity, wind speed and direction (see Section 4.1.3 for methodology of wind computation by JOSS), complete with quality flags, at 6-sec intervals from the surface to the top of each sounding, usually about 25 mb. These high resolution data were obtained by JOSS via diskettes from 14 NWS sites in the LSA-SW (Figure 3-14). Two sites moved during the ESOP-95 period. Monett, MO (UMN) moved to Springfield, MO (SGF) on 19 May 1995. El Paso, TX (ELP) moved to Santa Teresa, NM (EPZ) on 11 September 1995. All data were converted to a

common ASCII sounding format and quality controlled (see Section 4.1.4) by JOSS. These data are available from JOSS as the GCIP/ESOP-95 NWS High-Resolution Soundings Data Set.

NWS Upper Air Rawinsonde Data (mandatory/significant levels) - These data include 12-hourly vertical profiles of pressure, altitude, temperature, dew point, and wind speed and direction at all mandatory and significant levels. Data were routinely collected at 72 sites (approximately 400 km spacing) over all of the conterminous United States and archived at NOAA/NCDC. Data for the LSA-SW (see Figure 3-14) are archived and available at NCDC. They are available from JOSS as the NCDC NWS Rawinsonde (man/sig levels) Data Set which is a link to the NCDC OASIS data management system.

DOE ARM/CART Site Upper Air Data - The DOE ARM Program routinely obtained upper air observations, at 2-sec vertical resolution, at the Southern Great Plains CART site in Kansas and Oklahoma. These measurements include up to 3-hourly soundings of pressure, temperature, humidity, and wind at a central site and 4 boundary facilities in the LSA-SW (Figure 3-15). The data were collected and processed by the DOE ARM Program and archived at the DOE/ORNL. Data for the ESOP-95 period were extracted and forwarded to the JOSS. All data were converted to a common ASCII sounding format and quality controlled (see Section 4.1.4) by JOSS. These data are available from JOSS as the GCIP/ESOP-95 ARM-CART Soundings Data Set.

VORTEX Fixed and Mobile Site Upper Air Data - During the VORTEX-95 period (1 April to 15 June 1995) 10-sec vertical resolution upper air observations were obtained at up to four fixed sites (Altus, Ardmore, and Woodward, Oklahoma and Lubbock, Texas) and five mobile platforms [four National Severe Storms Laboratory (NSSL) and one National Center for Atmospheric Research (NCAR) platform(s)]. Data were only collected on selected days and at no specified schedule. The data were processed and archived both at NCAR/Surface and Sounding Systems Facility and JOSS. All data were converted to a common ASCII sounding format and quality controlled (see Section 4.1.4) by JOSS. These data are available from JOSS as the VORTEX-95 10 sec CLASS Soundings Data Set.

NOAA Profiler Network (NPN) Data - The NPN routinely collected vertical profiles of hourly component winds (u, v, and w) and six-minute radar return spectral moments, both with 250 meter resolution. The data were routinely collected and processed by NOAA/FSL and archived at NOAA/NCDC. The hourly wind profile data for the 16 profilers in the LSA-SW (Figure 3-16) were extracted and forwarded to the JOSS. JOSS converted these data to an ASCII format and it is available as the NOAA Wind Profiler Network Hourly Winds Data Set. The 6-minute spectral moments, diagnostic spectrum, Radio Acoustic Sounding System (RASS), and RASS spectral data are available from JOSS via links to the data sets on the NCDC OASIS data management system. The 60-minute averaged wind profiles, spectral moments, control, and RASS data are also available from JOSS via links to the data sets on the NCDC OASIS data management system.

3.1.3 Radar Data

WSR-88D Data - Data from the WSR-88D network (Figure 3-17) are divided into a number of archive levels depending upon the level of processing performed. Archive I is the raw engineering data; Archive II contains reflectivity and radial velocity information at the highest resolution and over each full volume scan of the radar; and Archive III contains operational products as graphics meta files from commissioned radars. Archive II provides the basis for all high level products while Archive III includes a variety of products including base level reflectivity and velocity data at 1 km by 1^{o} resolution and hourly precipitation at 4 km by 4 km. Since Archive III data are stored as graphics meta files, they are extremely difficult to work with digitally and are best used as hardcopy products. Included in the Archive III are some digital products, in particular the Digital Precipitation Array of hourly data on a 4 km by 4 km grid and the Supplemental Precipitation Product giving information on the performance of the precipitation algorithms and coarser resolution precipitation data. Archive II and III data were routinely archived and available at the NOAA/NCDC. Archive II data are available via JOSS as the NCDC WSR-88D Level II Data Set which is a link to the NCDC archive on their OASIS data management system.

WSR-88D NIDS Data - The NEXRAD (NEXt generation RADar) Information Dissemination Service (NIDS) data were collected by JOSS via the Weather Services International (WSI) through the Cooperative program for

Operational Meteorology, Education, and Training (COMET). NIDS products consist of selected information from the Level III database from each WSR-88D site (Table 3-2). For the VORTEX program NIDS data was collected from 12 sites (see Figure 3-17). Only the lowest two tilts of reflectivity and velocity, composite reflectivity, and Velocity Azimuth Display (VAD) data were collected for the period 1 April to 15 June 1995. These data are available from JOSS as the VORTEX-95 WSI NIDS Single Radar Data Set. For GCIP the same NIDS products were collected from seven radars (KTWX, KDDC, KICT, KINX, KFTG, KSGF, KTLX, and KVNX) for the period 15 June through 31 August 1995. A separate data set of the VAD data is available from JOSS as the GCIP/ESOP-95 WSI NIDS VAD Data.

WSI Reflectivity Composite Imagery - WSI routinely produced and distributed a mosaic of reflectivity from all NWS radars in the conterminous United States. The product, called NOWRAD, was available at a variety of resolutions and coverages in real time. For ESOP-95, 2 km data were recorded at 15 minute intervals in a fixed sector overlaying the LSA-SW. These images were obtained at the JOSS from the NOAA/National Severe Storms Forecast Center (NSSFC; presently the Storm Prediction Center [SPC]) in Kansas City, MO. From this data set a representative daily image was selected at 21 UTC, or the closest available time. The selected daily images were translated to GIF (Graphical Interchange Format). These imagery are available online from JOSS for browsing purposes as the GCIP/ESOP-95 Nowrad Imagery (GIF format) Data Set. The full 15-min data set in its original format is available directly from JOSS. Also, for STORM-WAVE, JOSS has made available daily (~ 2300 UTC) GIF imagery of 4 km nowrad data covering the continental US. These imagery are available as the GCIP/ESOP-95 and STORM-WAVE Radar Composite Imagery Data Set.

ABRFC Stage III WSR-88D Data - The ABRFC routinely produced hourly composite derived precipitation products from all the WSR-88D radars covering the Arkansas-Red River basins. These data are on a 4 km by 4 km grid and are in GRIB (GRid point values expressed in Binary format). These data were archived by NOAA/OH together with the Digital Precipitation Array and the Supplemental Precipitation Product (Stage I) and the Stage II hourly Precipitation Processing System products. Stage III data for ESOP-95 period were extracted and forwarded to JOSS. These data are available from JOSS as the GCIP/ESOP-95 NWS/OH Gridded Precipitation Data Set. Also, GIF imagery are available on-line from JOSS for browsing purposes as the GCIP/ESOP-95 ABRFC WSR-88D Stage III Daily Precipitation Data Set which has daily (~1200 UTC) total precipitation estimate GIF images and the GCIP/ESOP-95 ABRFC WSR-88D Stage III Hourly Precipitation Data Set which has hourly total precipitation estimate GIF images.

NASA/MSFC National Radar-derived Precipitation Rate Composite - The NASA/Marshall Space Flight Center (MSFC) produced precipitation rate imagery by converting WSI composite radar data to rainfall rates using the Z-R relation that is the default equation used by the NWS WSR-88D radars to generate a rainfall product. These are available from NASA/MSFC/Global Hydrology and Climate Center (GHCC) Distributed Active Archive Center (DAAC) with 8 km resolution in either GIF or HDF (Hierarchical Data Format). These files were translated to GIF and provided to JOSS. JOSS selected representative daily imagery at 1200 UTC (or the closest available time) and they are available for online browse purposes. These data are available from JOSS as the GCIP/ESOP-95 Radar-derived Precipitation Rate National Composite.

TABLE 3-2 WSR-88D NIDS Products and Descriptions

Reflectivity *
The first four tilt angles are available. The resolution is 1 km by 1.

Composite Reflectivity *
The maximum reflectivity observed at any level above a given part of the earth. The range is 460 km.

Echo Tops
The height in feet above mean sea level of the highest detected echo above a given location.

Vertically Integrated Liquid
Displays integrated liquid water values summed for all elevation angles within the volume scan. The range is 460 km.

Surface Rainfall Accumulation (1-hr)
One hour running total of surface rainfall accumulation. The resolution is 2 km by 2 km.

Surface Rainfall Accumulation (3-hr)
Three hour total surface rainfall accumulation (updated hourly). The resolution is 2 km by 2 km.

Storm Total Rainfall
Rainfall accumulated until no precipitation is detected for one continuous hour. The resolution is 2 km by 2 km.

Hourly Digital Rainfall Array
An hourly running total precipitation accumulation estimate in a derived array format.

Radial Velocity *
The speed toward or away from the radar antenna. The first four tilt angles are available. The resolution is 1 km by 1.

Velocity Azimuth Display *
Vertical wind profiles for up to ten time periods.

Layer Composite Reflectivity
Composites of reflectivity through a layer of the atmosphere. Three layers are available with the depths controlled by adaption data. The range is 450 km.

NOTE: Unless otherwise noted, the resolution is 4 km by 4 km and the range is 230 km.
NOTE: * NIDS products collected by JOSS

3.1.4 Land Characterization Data

Little Washita Basin Soils and Land Cover - These datahave been produced for the Little Washita Basin by the Grazinglands Research Laboratory (GRL) of the United States Department of Agriculture/ Agricultural Research Service (USDA/ARS) and are available from GRL.

PSU 1-km Multi-Layer Soil Characteristics Data - The Pennsylvania State University (PSU) has developed a 1-km Multi-Layer Soil Characteristics Data Set based on the USDA State Soil Geographic Database (STATSGO). This data set includes STATSGO mapunit coverage defined for the 48 conterminous states, soil texture class coverages (for 11 layers from the surface to 250 cm below ground), hydrologic soil groups, available water capacity, depth-to-bedrock coverage, sand/silt/clay fractions, rock fragment class, rock fragment volume, and porosity. Data are available in either vector (Arc/Info polygon format) or gridded (Arc/Info GRID format or as two-dimensional binary arrays) formats and a variety of map projections (Lambert Azimuthal, Albers Equal Area, and Geographic Coordinates). Data are processed and archived at the PSU Earth System Science Center. These data are available from JOSS as the PSU 1-km Multi-Layer Soil Characteristics Data Set which is a link to the data set at PSU.

3.2 Satellite Data

Unless otherwise specified the following satellite data sets are coordinated through the Satellite Data Source Module (NASA/MSFC). Further details by data set are provided below:

GOES-7/8 Satellite Imagery (IR, VIS, 6.7 micron) - Most of the satellite data for ESOP-95 were obtained from two geosynchronous Geostationary Operational Environmental Satellites (GOES-7/8) positioned near 135^{o} and 75^{o} longitude. The primary instrumentation on GOES-7/8 was the Visible (VIS) and Infrared (IR) Spin-Scan Radiometer (VISSR) which produced both day and night IR [10.5 to 12.5 micrometers] and day VIS [0.5 to 0.7 micrometers] radiometric images of the full disk at 30-min intervals. In addition, the VISSR Atmospheric Sounder (VAS) sensor had four infrared detectors and 12 narrow band filters that produces multi-spectral data [from 14.73 to 3.95 micrometers]. During ESOP-95, image frequency was occasionally increased by placing the satellites into Rapid Interval Scan Operations Plan (RISOP) mode or "Rapid Scan". Under RISOP, up to 60 VIS/IR images per hour could be obtained depending on location of interest. Note that during RISOP, normal, scheduled VAS operations could have been suspended or changed. These data were routinely archived by NOAA/National Environmental Satellite Data and Information Service (NESDIS)/NCDC at the University of Wisconsin's Space Science Engineering Center (SSEC). For the LSA-SW, JOSS collected GOES-8 VIS (1 km) and IR (4 km) imagery every 30-min, and water vapor (WV) (6.7 micrometers) imagery (8 km) every hour from the NOAA/NSSFC. Daily (~ 1200 UTC for IR and WV and ~ 2100 UTC for VIS) GIF imagery of these data are available from JOSS as the GCIP/ESOP-95 GOES-8 IR Images Data Set, the GCIP/ESOP-95 GOES-8 VIS Images Data Set, and the GCIP/ESOP-95 GOES-8 WV Images Data Set.

GOES-7/8 VAS Data/Derived Products - The GOES-7/8 VISSR Atmospheric Sensor (VAS) provided IR radiance observations at 12 wavelengths between 3.9 and 14.7 micrometers as well as two imaging modes (6.9 to 13.8 km resolution) and a sounding mode (13.8 km resolution). Meteorological parameters derived from VAS (for clear and partly cloudy areas) include: cloud cover, earth/cloud temperatures, cloud type, cloud motion derived winds, stereo derived cloud-top heights, water vapor fields, temperature fields, improved surface temperatures, and temperature and moisture profiles (dwell soundings). The interval and number of dwell soundings and derived products depended upon whether the satellites were in normal operation or RISOP mode. VAS data were routinely archived by NOAA/NESDIS/NCDC at the University of Wisconsin's SSEC.

NOAA POES AVHRR Imagery - Two NOAA series Polar Orbiting Environmental Satellites (POES; NOAA-12 and NOAA-14) carried the Advanced Very High Resolution Radiometer (AVHRR). AVHRR is a cross-track scanning system with five spectral channels in the visible, near-infrared, and infrared [0.58 to 12.50 micrometers]. The normal operating mode of the satellites results in continuous High Resolution Picture Transmission (HRPT) to earth, where the data are recorded by a network of ground stations. AVHRR data include 1-km resolution HRPT or LAC (Local Area Coverage) and 4-km resolution GAC (Global Area Coverage) resolution imagery (1600 km swath) during subsequent sun-synchronous morning/evening ascending and descending passes (up to 4 passes daily). AVHRR data were routinely collected, processed, and archived at NOAA/NESDIS/NCDC.

NOAA POES TOVS Data - Two NOAA series polar orbiting satellites (NOAA-12 and NOAA-14) carried the microwave Television and Infrared Observation Satellite (TIROS) Operational Vertical Sounder (TOVS). The TOVS system consists of four separate sensors: (1) High Resolution Infrared Radiation Sounder (HIRS/2), which measures incident radiation primarily in the infrared; (2) Microwave Sounding Unit (MSU), a passive scanning microwave spectrometer with 4 channels (5.5 micrometer region); (3) Stratospheric Sounding Unit (SSU), a step-scanned far-infrared spectrometer with three channels (15 micrometer region); and (4) Solar Backscattered Ultraviolet system (SBUV/2), which maps total ozone concentrations and vertical ozone distributions. Data are collected (1600 km swath) during subsequent sun-synchronous morning/evening ascending and descending passes (up to 4 passes daily). TOVS data were routinely collected, processed, and archived at NOAA/NESDIS/NCDC.

DMSP SSM/I Data/Imagery - The United States Air Force (USAF) operates the Defense Meteorological Satellite Program (DMSP) which is a system of three near polar orbiting satellites (F10, F12, and F13) that provide global microwave data from the Special Sensor Microwave Imager (SSM/I). The SSM/I sensor provides water vapor measurements (1400 km swath) at three frequencies (19.35, 37.0, and 85.5 GHz). DMSP data were routinely archived at the National Snow and Ice Data Center (NSIDC) at Boulder, CO.

NOAA Weekly Northern Hemisphere Snow Cover Analysis - NOAA weekly snow cover analyses were created on a hemispheric map and faxed to the NCDC from the NESDIS Synoptic Analysis Branch. The analysis was done over a 7-day period and extends from 35° to 67°N latitude. Because of the use of satellite techniques, the analysis was not done beyond 67°N latitude since there were mostly dark hours. The categories in the analysis were snowcover, patchy snowcover, ice, and open. Each analysis clearly indicates which imagery sources were used to identify the ice. Satellite imagery used includes GOES, POES, GMS (Geostationary Meteorological Satellite), and METEOSAT (Meteorological Satellite). These analyses were archived at NCDC and are available via FAX subscription.

GOES/ASOS Cloud Observations - The GOES/ASOS cloud height and amount data were archived by NESDIS. ASOS stations have been installed and commissioned at many surface sites across the United States. It will eventually replace manual observations at as many as 1700 locations. ASOS collects meteorological data from a suite of instruments, merges the data into SAO format, and transmits it to various communications circuits such as the NWS Automated Field Operations and Services (AFOS) and Family of Services (FOS) networks. A limitation of ASOS is that it does not detect cloud bases above 12,000 feet. To compensate for this limitation, a satellite-based ASOS processing system has been developed to detect cloud height and fractional cloud amount for the middle and upper levels of the atmosphere. The current ASOS processing system uses data from GOES-7 Visible and Infrared Spin Scan Radiometer (VISSR) Atmospheric Sounder (VAS) and is generated on the VAS Data Utilization Center (VDUC) computer system located in Camp Springs, MD at hourly intervals. The GOES-8 ASOS processing system will use data from the GOES-8 sounder instrument and will be generated on an IBM RS/6000 workstation at hourly intervals.

Extraction of cloud height and amount is accomplished by means of the "CO_2 slicing" technique which calculates the cloud information from radiative transfer equations. The technique uses multi-spectral IR data in the CO_2 and longwave window channels, as well as ancillary surface and numerical forecast temperature and moisture profiles. Solution of the radiative transfer equations results in the determination of cloud top pressure and effective cloud amount. Application of empirical decision trees results in a composite cloud height and amount for a 40 by 40 km area centered on a particular ASOS station. The availability dates of these data to external requesters has not been confirmed at this writing.

CLAVR Clouds - The CLouds from AVhRr (CLAVR) product was in development within NOAA/NESDIS during the ESOP-95 period. Version 1 was developed and used within NESDIS. During ESOP-95, Version 2 was being produced for developmental purposes. Users wanting access to these data should contact the GCIP Satellite Data Source Module (SDSM).

Satellite Radiation Data Sets - These products use five channels of GOES-8 data, Eta model forecasts, and USAF snow cover analyses to create gridded 1° resolution products in the domain defined by 20°-50°N and 65°-125°W. These images are available hourly and are online via the GCIP SDSM home page. The products were reviewed and validated during the ESOP-95 period. A list of the available products is in Table 3-3. These data have been archived by the producer and may be obtained by request from the GCIP SDSM.

TABLE 3-3 Satellite Radiation Data Sets

Mean radiance (channel 1)
Mean radiance (channel 2)
Mean radiance (channel 3)
Mean radiance (channel 4)
Mean radiance (channel 5)
Clear sky composite radiance
Number of clear pixels
Number of cloudy pixels
Snowcover
Standard deviation of channel 1

Standard deviation of channel 4
Precipitable water
Temperature at first level above surface
Surface pressure
Surface downward flux (clear + cloudy)
Surface upward flux (clear + cloudy)
Top of atmosphere downward flux (clear + cloudy)
Top of atmosphere upward flux (clear)
Surface downward flux (clear)
Surface downward flux (cloudy)

EDC Bi-Weekly Vegetation Index Data - Satellite-derived values of vegetation index were routinely produced at NOAA/NESDIS and the Earth Resources Observation Systems (EROS) Data Center (EDC) at Sioux Falls, SD. One set of data at 1 km resolution was available bi-weekly from the EDC while another set at 15 km resolution was available weekly from the NOAA/NESDIS in Washington, D.C. The land cover imagery were produced bi-weekly from 1 km resolution AVHRR and translated to GIF by the USGS EDC. The full land characteristics database is available on CD-ROM from EDC. GIF imagery data for the ESOP-95 period were extracted and forwarded to the JOSS from the EDC. These data are available from JOSS as the GCIP/ESOP-95 EDC Derived Vegetation Index Data Set.

3.3 Model Output

3.3.1 Atmospheric model output

Unless otherwise specified the following atmospheric model output are coordinated through the Model Output Source Module [NCAR/Scientific Computing Division (SCD)]. Further details by output set are provided below:

The emphasis for model output during ESOP-95 was on the regional mesoscale models with output from the following three models:

(i) NOAA/National Centers for Environmental Prediction (NCEP) Eta Model
(ii) Atmospheric Environment Service/Canadian Meteorological Centre (AES/CMC) Regional Finite Element (RFE) Model
(iii) NOAA/FSL Mesoscale Analysis and Prediction System (MAPS) Model

The outputs from these models follow the guidelines of the GCIP Implementation Plan, Vol I, Section 5 (IGPO, 1993) and are divided into three parts:

(1) One-dimensional vertical profile and time series at selected locations, referred to as Model Location Time Series (MOLTS).

(2) Gridded two-dimensional fields, especially ground surface state fields, ground surface flux fields, top-of-the-atmosphere flux fields, and atmospheric fields, referred to as Model Output Reduced Data Set (MORDS).

(3) Gridded three-dimensional atmospheric fields containing all of the atmospheric variables produced by the models.

NOAA/NCEP Eta Model Output - The NOAA/NCEP [formerly NOAA/National Meteorological Center (NMC)] provided operational output from its regional Eta model including output from the Eta Data Assimilation System (EDAS). The Eta operated in analysis and forecast cycles at 6-hr intervals with forecasts provided up to 24 hours. The EDAS was also run at the intermediate 3-hourly intervals to produce eight analyses per day. The horizontal resolution of the Eta model output provided to GCIP was constant at a 40 km resolution independent of the resolution of the operational model. The vertical resolution of the 3-D atmospheric fields provided to

GCIP was constant (25-mb intervals from 1000 to 50 mb) independent of the resolution of the operational model. These output were archived by NCAR/SCD.

NOAA/NCEP Eta Initial Analysis Daily GIFs - The NSSL routinely collected NOAA/NCEP Eta model initial analyses. The JOSS received these analysis plots and converted them to GIF imagery. The Eta model analysis covers most of North America, and images are available for the 12 UTC Eta model run at 1000, 850, and 500 mb. GIF imagery for the ESOP-95 period were archived by JOSS and are available for the purpose of summarizing the surface and upper-air conditions during ESOP-95. These images are available from JOSS as the GCIP/ESOP-95 NMC eta 1000mb Maps Data Set, the GCIP/ESOP-95 NMC eta 850mb Maps Data Set, and the GCIP/ESOP-95 NMC eta 500mb Maps Data Set.

NOAA/NCEP Eta Model Location Time Series (MOLTS) - The NOAA/NCEP Eta model provided vertical and hourly time series of model output (MOLTS) at selected locations. The output variables for both the "enhanced" and "basic" versions of the Eta MOLTS during the ESOP-95 period are shown in Table 3-4. The Eta MOLTS "enhanced" output were available from 258 locations, and the "basic" output were available from 529 locations, over North America (Figure 3-18). Depending on the surface pressure, there were up to 38 vertical levels. Output were provided from the 00 and 12 UTC model runs from the initial analysis time out to the 48 hour forecast. These output were archived in BUFR (Binary Universal Form for Data Representation) format at NCAR/SCD.

TABLE 3-4 Output Variables for the Eta Model MOLTS During ESOP-95

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1) Identifiers

Station ID number
Cycle
Forecast time
Station latitude
Station longitude
Station elevation
Number of surface parameters
Number of sounding parameters
Number of sounding levels

2) Surface Parameters

Mean sea level pressure
Surface pressure
Skin temperature
Minimum temperature over hour
Maximum temperature over hour
Surface moisture availability
Total precipitation in last hour
Convective precipitation in last hour
Snow precipitation type
Ice pellet precipitation type
Freezing rain precipitation type
Rain precipitation type
Latent heat flux
Potential flux of latent heat
Sub-surface heat flux
Sensible heat flux
Snow phase-change heat flux
Short-wave radiation flux downward
Short-wave radiation flux upward

Long-wave radiation flux downward
Long-wave radiation flux upward
Net long-wave radiative flux at top of atmosphere
Net short-wave radiative flux at top of atmosphere
Soil temperature
Soil moisture
Snow water equivalent
Snow melt
Surface runoff
Baseflow-groundwater runoff
Bottom soil temperature
Roughness length
U-wind component at 10 m
V-wind component at 10 m
Potential temperature at 10 m
Specific humidity at 10 m
Temperature at 2 m
Specific humidity at 2 m
U component of storm motion
V component of storm motion
Storm relative helicity

3) Atmospheric Variables at Each Model Vertical Level

Pressure
Temperature
U-wind component
V-wind component
Specific humidity
Omega (vertical motion)
Convective precipitation latent heating rate
Stable precipitation heating rate
Shortwave radiation latent heating rate
Longwave radiation latent heating rate
Cloud water mixing ratio
Cloud fraction in a layer

NOTE: Items in **bold face** are available in the "basic" MOLTS

Eta MOLTS Derived Sounding Output - JOSS extracted the MOLTS output from the basic MOLTS locations within the LSA-SW for the Eta model (see Figure 3-18). These output were then processed and converted to a format similar to that used by JOSS for the actual atmospheric sounding data (i.e. NWS, VORTEX, and ARM/CART). This was done by stripping out the state parameters at the surface and each model level. Only the 00 hour initial analysis time was processed. Output are available for each model analysis time (00 and 12 UTC). This output is provided to allow intercomparison studies. These output were archived at JOSS. These data are available from JOSS as the GCIP/ESOP-95 Eta MOLTS Derived Soundings Data Set.

AES/CMC RFE Model Output - The AES/CMC provided operational output from the RFE model including output from its data assimilation system. The RFE operated in analysis and forecast cycles at 6-hr intervals with forecasts up to 24 hours. The horizontal resolution of the model was 50 km over the LSA-SW with an upgrade to 35 km during the ESOP-95 period. The vertical resolution was 23 levels at a variable spacing. Model output were archived by the AES/CMC.

MORDS Output - An analysis of the different GCIP requirements for the gridded two- and three-dimensional fields indicates that most of the requirements can be met by a selected set of two-dimensional gridded fields. [NOTE: Some of the requirements for three-dimensional fields can also be met with the MOLTS, e.g. by placing the locations around the boundaries of a river basin to do budget studies. Some of the other three-dimensional field requirements can be met by a vertical integration through the atmosphere, e.g. vertically integrated atmospheric moisture divergence needed to calculate water budgets]. GCIP will make use of this concentration of requirements to further tractability of the model output handling problem. A Model Output Reduced Dataset (MORDS) was produced as two-dimensional fields with the expectation that the MORDS can meet most of the GCIP requirements at a significantly reduced data volume over that needed to provide the information as three-dimensional fields. GCIP is proposing a total of 60 output variables for MORDS separated into the following four components:

(1) Near-surface fields which include all the sub-surface and surface land characteristics and hydrology variables plus the surface meteorological variables including wind components at 10 m.

(2) Lowest-level atmospheric fields which includes the lowest model level and the mean value in a 30 hPa layer above the surface.

(3) Upper atmosphere fields at a few standard levels plus the tropopause height and the top-of-the-atmosphere radiation as a time average.

(4) Metadata fixed fields as one-time companion file to the MORDS.

The specific model output variables in each of the four components are listed in Table 3-5. The output from the three models may not include all of the variables listed in Table 3-5, and this fact will be a part of the metadata provided with the specific model output. For the ESOP-95 period, only the Eta and RFE models provided MORDS output. For more information on the Eta output contact the GCIP Model Output Source Module. The RFE output were archived by AES/CMC.

TABLE 3-5 MORDS Output Variables

Near-Surface Fields

Mean sea level pressure
Surface pressure at 2 m
Temperature at 2 m
Specific humidity at 2 m
U component of the wind at 10 m
V component of the wind at 10 m
Surface latent heat flux (time average)
Surface sensible heat flux (time average)
Ground heat flux (time average)
Snow phase change heat flux (time average)
Surface momentum flux (time average)
Vertically integrated moisture convergence (time average)
Vertically integrated energy convergence (time average)
Total precipitation (time accumulated)
Convective precipitation (time accumulated)
Surface runoff (time accumulated)
Subsurface runoff (time accumulated)
Snow melt (time accumulated)
Snow depth (water equivalent)
Total soil moisture (within total active soil column)
Canopy water content (if part of surface physics)

Surface skin temperature
Soil temperature in top soil layer
Surface downward shortwave radiation (time average)
Surface upward shortwave radiation (time average)
Surface downward longwave radiation (time average)
Surface upward longwave radiation (time average)
Total cloud fraction (time average)
Total column water vapor
Convective Available Potential Energy

Lowest-Level Atmospheric Fields

Temperature (lowest model level)
Specific humidity (lowest model level)
U component of the wind (lowest model level)
V component of the wind (lowest model level)
Pressure (lowest model level)
Geopotential (lowest model level)
Temperature (mean in 30 hPa layer above ground)
Specific humidity (mean in 30 hPa layer above ground)
U component of the wind (mean in 30 hPa layer above ground)
V component of the wind (mean in 30 hPa layer above ground)

Upper Atmospheric Fields

1000 hPa height 700 hPa vertical motion 850 hPa height 850 hPa temperature 850 hPa specific humidity
850 hPa U component of the wind
850 hPa V component of the wind
500 hPa height
500 hPa absolute vorticity
250 hPa height
250 hPa U component of the wind
250 hPa V component of the wind
Tropopause height (or pressure)
Top-of-the-atmosphere net longwave radiation (time average)
Top-of-the-atmosphere net shortwave radiation (time average)

Metadata Fixed Fields (as one-time companion file to MORDS)

Model terrain height
Model roughness length
Model maximum soil moisture capacity
Model soil type
Model vegetation type

NOAA/FSL MAPS Model Output - The NOAA/FSL ran the MAPS model every 6 hours (00, 06, 12, and 18 UTC) with up to 6 hour forecasts at a standard resolution of 60 km over the LSA-SW during the VORTEX project. Standard fields were available at 25 levels from the surface to 100 mb. The data cutoff for model runs was approximately 1 hour, and the output format was GRIB. Since this model was run to support VORTEX, output for the LSA-SW are available for 1 April through 15 June only. These output are available from JOSS as the VORTEX-95 MAPS Analyses/Forecasts Data Set and the VORTEX-95 MAPS Surface Analyses Data Set.

3.3.2 Hydrologic model output

The NOAA/OH provided operational model output from the National Weather Service River Forecast System (NWSRFS) from the River Forecast Centers (RFC) in the Mississippi River basin. The NWSRFS is a system which integrates a variety of hydrological models into a comprehensive river forecast system. It includes models of runoff-generating processes and runoff and streamflow routing. For ESOP-95, model output from the ABRFC were archived and made available by NOAA/OH.

The NWSRFS model output includes values every six hours of all of the available elements of the daily water budget: precipitation, runoff (surface runoff and baseflow), evaporation and soil moisture storage for individual soil moisture accounting (SMA) areas and the downstream routed streamflows. These output sets enable surface water budgets to be made over large areas for verification of atmospheric and coupled atmospheric-hydrological models. Table 3-6 lists the RFC model outputs proposed by the NOAA/OH.

TABLE 3-6 RFC Hydrological Six-hour Model Outputs Proposed by NOAA/OH for GCIP

Mean Areal Precipitation
Mean Areal Air Temperature
Mean Areal Snow Water Equivalent[1]
Percent of Areal Extent of Snow Cover
Heat Deficit in the Snow Pack
Mean Areal Rain Plus Melt from Snowmelt Model
Mean Areal Potential Evaporation[2]
Upper Zone Tension Water Storage
Upper Zone Free Water Storage (UZFW)
Lower Zone Tension Water Storage
Lower Zone Primary Free Water Storage
Lower Zone Secondary Free Water Storage
Additional Impervious Area (fraction of basin area)
Impervious runoff from permanent impervious areas and direct runoff from temporary impervious areas
Surface runoff when UZFW is full and precipitation intensity exceeds the rate of percolation and interflow
Interflow resulting from the lateral drainage of the UZFW
Supplementary Baseflow
Primary Baseflow
Subsurface Outflow
Total Runoff
Streamflow from SMA at outlet
Routed Streamflow from Areas Above SMA
Forecast Streamflow After Blending with Observed Streamflow
Computed SMA Daily Evaporation for Model Water Balance[3]

[1]Snow water equivalents and snowmelt may be calculated for several contour increments within an SMA in mountainous areas.

[2]Mean areal potential evaporation is computed on a daily basis and the six-hour values are simply 1/4 of the daily total.

[3]Because the potential evaporation forcing is a daily average, the six-hour evaporation amounts do not include diurnal variability and a daily sum is given.

4. SPECIAL PROCESSING

This section includes summaries of some of the special processing that occurred relative to data collected during ESOP-95.

4.1 In-Situ

This section discusses the quality control (QC) of the surface and precipitation composites created for ESOP-95. Detailed descriptions of the components of the composite datasets are provided in Section 3. Uniform QC procedures were applied during the compositing process. Brief descriptions of the QC processes follow.

4.1.1 QC of ESOP-95 Surface Composites

The ESOP-95 5-minute, 20-minute, and Hourly Surface Composites were formed by an aggregation of data sets from several surface meteorological networks (Figure 4-1). This figure is for the Hourly Surface Composite, the 5-minute and 20-minute Surface Composites are similar except in the data sets included. Selected parameters from each data set were quality controlled by the use of horizontal quality control procedures.

During the JOSS Horizontal Quality Control (JOSS HQC) processing, station observations of pressure, temperature, dew point, wind speed, and wind direction were compared to "expected values" computed using an objective analysis method adapted from that developed by Cressman (1959) and Barnes (1964). The JOSS HQC method allowed for short term (30 day) variations by using 30 day standard deviations computed for each parameter when determining the acceptable limits for "good", "questionable", or "unlikely" flags. "Expected values" were computed from inverse distance weighted station observations within a 300 km radius of influence (ROI) centered about the station being quality controlled (the station being quality controlled was excluded); i.e.;

Where $_e$ is the "expected value" of the parameter at the site in question, w_i is the weighting factor for site i (here the inverse of the distance between site i and the station being quality controlled), s is the number of stations within the ROI that have valid observations of the parameter at the time in question, and $_o(i)$ is the observed value of the parameter at site i.

To determine an observation's HQC flag setting, the difference between the actual observation and its "expected value" was compared to that parameter's normalized standard deviation. Normalizing factors (also called the sensitivity coefficients) were chosen to control the "good", "questionable", and "unlikely" flag limits for each parameter. See Table 4-1 for ESOP-95 normalizing factors. Table 4-2 contains the HQC flag limit ranges derived from the normalizing factors given in Table 4-1 and estimated standard deviations for each parameter so that 95% of the QC limits applied to the ESOP-95 data fell within these ranges. For example, 95% of the observed station pressure values that were flagged as "good" were within 1.5 mb of the expected value. The significant overlap of the ranges seen in Table 4-2 was partially due to seasonal and station differences in standard deviations. The actual HQC limits applied at any particular time depended upon the dynamic nature of the particular station's parameter values over time.

Data were never changed, only flagged.

HQC was only applied to station pressure, sea level pressure, calculated sea level pressure, temperature, dew point, wind speed and wind direction. If the calculated sea level pressure quality control information was available, its flag was applied to the station and sea level pressures. If the calculated sea level pressure could not be quality controlled, the sea level pressure quality control flag was applied to the station pressure. If the sea level pressure could not be quality controlled, the station pressure quality control flag was not overridden.

Table 4-1 Normalizing Factors used for ESOP-95 Surface Composites

Parameter	Good	Questionable	Unlikely
Station Pressure	0.2	0.2	0.5
Sea Level Pressure (SLP)	0.2	0.2	0.5

Calculated SLP	0.4	0.4	1.0
Dry Bulb Temperature	0.5	0.5	1.0
Dew Point Temperature	0.5	0.5	1.0
Wind Speed	2.25	2.25	4.0
Wind Direction	1.22	1.22	2.2

Table 4-2 Ranges of HQC Flag Limit Values for the ESOP-95 Surface Composites

Parameter	Good	Questionable	Unlikely
Station Pressure	< 1.5	[0.7-3.9]	> 1.7
Sea Level Pressure (SLP)	< 1.7	[0.5-4.3]	> 1.2
Calculated SLP	< 3.9	[0.9-9.8]	> 2.2
Dry Bulb Temperature	< 2.9	[1.2-5.8]	> 2.4
Dew Point Temperature	< 3.2	[1.2-6.3]	> 2.4
Wind Speed	< 7.4	[3.2-13.2]	> 5.6
Wind Direction	< 156.8	[94.6-180.]	> 170.5

General consistency checks were also applied to the dry bulb temperature, wind direction, and the relationship between precipitation and cloud amount/cloud cover. If the dew point temperature was greater than the dry bulb temperature both values were coded "questionable". Also, wind direction for observed "calm" winds was given the same QC code as the wind speed. If precipitation was reported, but the cloud amount was "none" or "clear", then both the cloud amount and precipitation values were coded "questionable".

Several impossible values were also checked. Negative wind speeds were coded "unlikely". Negative squall/gust wind speeds were coded "unlikely". Wind directions of less than 0^{o} or greater than 360^{o} were coded "unlikely". If these consistency checks would have upgraded the quality control flags previously set by HQC or gross limit checks they were not applied. However, if these consistency checks would have degraded the previously set QC flags, they were applied.

The JOSS HQC scheme relied on spatial and temporal continuity to flag the data. It has been shown that the method works very well for temperature, dew point, pressure, and wind speed, but is not a very good scheme for the wind direction. The flags appear to be overly lax and perhaps could be tightened.

4.1.2 QC of ESOP-95 Precipitation Composites

The ESOP-95 15-min, hourly, and daily precipitation composites were formed from an aggregation of datasets from several surface precipitation networks (Figure 4-2). The schematic shows the processing steps involved in

the preparation of the hourly precipitation composite. The 15-min and daily composites are produced in a similar fashion except that they used other segments of the data as described in Section 3.1.1. Each data set was quality controlled by the use of a series of global limit checks

Gross limit checks were used to flag the precipitation values. The gross limits are shown in Table 4-3. Certain "questionable" and "unlikely" data values were also manually inspected. After inspection, the quality control flag may have been manually modified to better reflect the physical reasonableness of the data. Data were never modified, only flagged. Negative precipitation were also coded "unlikely".

TABLE 4-3 QC Limits Applied to Precipitation Values for ESOP-95 Precipitation Composites.

Parameter	Good	Questionable	Unlikely
5-minute Precipitation	< 3 mm	3-6 mm	>= 6 mm
15-minute Precipitation	< 8 mm	8-18 mm	>= 18 mm
Hourly Precipitation	< 20 mm	20-50 mm	>= 50 mm
Daily Precipitation	< 101.6 mm	101.6-127 mm	>= 127 mm

4.1.3 Computation of High-Resolution Winds from NWS Rawinsonde Data

The raw data files provided by the NWS do not have wind speed and direction information, only elevation and azimuth angle data are provided. The use of the raw 6-sec resolution elevation and azimuth angle data to derive the winds sometimes led to large oscillations in wind speed, due to the presence of oscillations in the elevation angle data, particularly at low elevation angles. The general approach to correct this problem was to remove the outlier radiosonde position data before computing the wind components (Williams et al. 1993). For both the azimuth and elevation angles from 360 sec to the end of the sounding, a ninth order polynomial was fit to the curve. The residuals were calculated and compared to the observed values. The outliers of the residuals were then removed.

Then to help correct the more extensive problems at low elevation angles within 10^o of the limiting angles (LA) some additional smoothing was applied. If the elevation angle was between (LA + 7.5^o) and (LA + 10^o), the new elevation angle was computed with a 2 min linear fit. If the elevation angle was between (LA + 5^o) and (LA + 7.5^o), the new elevation angle was computed with a 3 min linear fit. If the elevation angle was less than (LA + 5^o), the new elevation angle was computed with a 4 min linear fit. If the number of observations with low elevation angles was greater than 20% of the total number of observations for the sounding no frequency smoothing occurred.

Then, for the elevation angle only, a finite Fourier analysis was performed on the residuals. Periods from 90-190 sec were removed and those below 30 sec were flattened.

Finally, a 2 min second order polynomial was then fit to the position to derive the u and v wind components, except for the beginning and end minute (or 1.5 minutes if over 50 mb) which used a 3 min fit. If there were less than 15% of the total number of points, not counting the beginning or end of the flight, on one side of the point for which the wind value was being computed, a linear fit was used.

For further information on this methodology and its changes since Williams et al. (1993) please see Williams, et al. (1998).

4.1.4 Quality Control of High Resolution Rawinsonde Data for GCIP

The NWS and VORTEX sounding data processed by JOSS underwent a two-stage QC process (the ARM/CART sounding data underwent only the first QC step). First, the data sets underwent internal consistency checks. This included two types of checks, gross limit checks on all parameters and rate-of-change checks on temperature, pressure and ascension rate. Second, each sounding was visually examined to verify those parameters that are too variable for automatic checks (wind speed, wind direction and moisture). This stage of the QC process also allows for a verification of the QC flags generated by the automatic checks. Some further information on the QC processing conducted by JOSS can be found in Loehrer et al. (1996) and Loehrer et al. (1998).

4.1.4.1 Gross Limit Checks

These checks were conducted on each of the soundings and data were automatically flagged as appropriate. They verified that the values of each parameter were within reasonable limits for a mid-latitude warm-season atmosphere. Only the data point under examination was flagged. The gross limits checks that JOSS applied to the GCIP/ESOP-95 sounding data sets are shown in Table 4-4.

4.1.4.2 Vertical Consistency Checks

These checks were conducted on each of the soundings and data were automatically flagged as appropriate. They are more stringent than the gross limit checks. These checks were started at the lowest level of the sounding and compared neighboring data points (except at for NWS soundings at pressures less than 100 mb where 30-sec average values were used, and for ARM/CART soundings where 6-sec average values were used at all pressures). There are two basic types of vertical consistency checks that are applied. The first group ensures that parameters that should increase/decrease do so. The second type ensured that parameters did not change more rapidly than they should (this includes superadiabatic and ascent rate checks among others). In the case of checks ensuring that the values increased/decreased as expected, only the data point under examination was flagged. However, for the other checks, all of the data points used in the examination were flagged. The vertical consistency checks applied by JOSS to the GCIP/ESOP-95 sounding data sets are shown in Table 4-5.

TABLE 4-4 Gross Limit Checks Applied to GCIP/ESOP-95 Sounding Data Sets

Parameter	Gross Limit Check	Parameter(s) Flagged	Flag Applied
Pressure	< 0 mb or > 1030 mb	P	B
Altitude	< 0 m or > 35000 m	P, T, RH	Q
Temperature	< -80C or > 45C	T	Q
Dew Point	< -99.9C or > 30C	RH	Q
	> Temperature	T, RH	Q
Relative Humidity	< 0% or > 100%	RH	B
Wind Speed	< 0 m/s or > 100 m/s	U, V	Q
	> 150 m/s	U, V	B
U Wind Component	< 0 m/s or > 100 m/s	U	Q

	> 150 m/s	U	B
V Wind Component	< 0 m/s or > 100 m/s	V	Q
	> 150 m/s	V	B
Wind Direction	< 0 deg or > 360 deg	U, V	B
Ascent Rate	< -10 m/s or > 10 m/s	P, T, RH	Q

NOTE: P = pressure, T = temperature, RH = relative humidity, U = U wind component, V = V wind component, B = bad, and Q = questionable.

TABLE 4-5 Vertical Consistency Checks Applied to GCIP/ESOP-95 Sounding Data Sets

Parameter	Vertical Consistency Check	Parameter(s) Flagged	Flag Applied
Time	decreasing/equal	None	None
Altitude	decreasing/equal	P, T, RH	Q
Pressure	increasing/equal	P, T, RH	Q
	> 1 mb/s or < -1 mb/s	P, T, RH	Q
	> 2 mb/s or < -2 mb/s	P, T, RH	B
Temperature	< -15 C/km	P, T, RH	Q
	< -30 C/km	P, T, RH	B
	> 5 C/km (not applied at p $lt; 150mb)	P, T, RH	Q
	> 30 C/km (not applied at p $lt; 150mb)	P, T, RH	B
Ascent Rate	change of > 3 m/s or < -3 m/s	P	Q
	change of > 5 m/s or < -5 m/s	P	B

NOTE: P = pressure, T = temperature, RH = relative humidity, U = U wind component, V = V wind component, B = bad, and Q = questionable.

4.1.4.3 Visual Quality Control Procedures

Each NWS and VORTEX sounding was then visually examined for problems that were not able to be captured via the automated checks described in Sections 4.1.4.1 and 4.1.4.2 above. These problems typically included oddities in the dew point and wind profiles. These two parameters can be highly variable, and hence, the

automated checking is more difficult. The visual checking procedure has two main purposes: First, as a check on the results provided by the automatic checks, and second, as a more stringent check on the more variable parameters. Some further information on the visual QC processing conducted by JOSS can be found in Loehrer et al. (1996) and Loehrer et al. (1998).

4.1.4.4 Data Quality Issues in NWS Rawinsonde Winds

4.1.4.4.1 Near Surface Winds

A common problem in near surface wind speed values calculated from the 6-second position data is that the first radiosonde wind speed is much higher than the independently measured surface value. The calculated radiosonde winds then decrease rapidly so that within about 60 s (20-30 mb) after release the wind speeds are more realistic. The cause of this appears to be the acceptance of radiosonde position data prior to a "good lock" being achieved on the radiosonde by the tracking system. Thus there appear to be rapid positional shifts of the radiosonde while the tracking system "searches" for the radiosonde. For more information on this problem please see Williams, et al. (1998).

4.1.4.4.2 Wind Oscillations

Despite the extensive efforts to remove oscillations in wind speeds caused by oscillations in elevation angles (see Section 4.1.3) there are occasional cases with remaining oscillations. Most of the remaining oscillations have periods just slightly longer than the 190 s maximum point of our notch filter. For more information on this problem please see Williams, et al. (1998).

5. DATA DISSEMINATION

Data for the ESOP-95 are primarily distributed to the GCIP community in two ways: (1) through on-line access, providing on-line transfer and off-line media; and (2) CD-ROM. Further details are provided in the following subsections.

5.1 ESOP-95 On-line Data Access

The ESOP-95 data are available on-line from the GCIP Data Management and Service System (DMSS). The DMSS provides a central information source for GCIP. It provides overviews and up-to-date information regarding GCIP and the DMSS. Also provided are links to the four GCIP data source modules that specialize the GCIP data sets by type. The modules include the in-situ data, model output, satellite remote sensing, and special GCIP data set modules. Figure 5-1 depicts the DMSS structure. The WWW home page for GCIP and the DMSS is at the following URL:

http://www.ogp.noaa.gov/gcip/

It contains overview information and scientific objectives on GCIP and the DMSS, references and published papers, access to selected on-line GCIP publications, and electronic links to each of the GCIP data source modules. The locations of each of the modules are discussed in the following subsections, except for the special GCIP data sets module which has not yet been implemented.

5.1.1 The In-situ Data Source Module

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The ESOP-95 In-situ data are available through the UCAR/JOSS Distributed Data Management System also known as CODIAC. CODIAC is an on-line, interactive data management system that consists of a data catalog, data inventories, station descriptions, and an order entry system. CODIAC is a distributed system that allows the user to link to other centers with on-line data systems (e.g. NCDC) for further information on data sets and data delivery. CODIAC provides information about each field projects' data sets by title, abstract, time, location, and frequency of observations. Detailed information on stations and observing platforms include station name and location as well as observed parameters.

The user may browse selected data sets. This includes time series plots for surface parameters, skew-T/log-p diagrams for soundings, as well as GIF images for radar composites, model analyses, and satellite imagery.

CODIAC also allows users to directly retrieve data. On-line dat a sets may be downloaded via the Internet or can be sent via magnetic media (i.e. 9-track, Exabyte, or Digital Audio tape). Off-line data are available only via magnetic media. The user can use WWW "forms" to order the data on-line. Most data may be selected by time and/or location and are available in one or more formats depending on the data set in question. Any documentation concerning the data itself, processing steps, or quality control procedures used is automatically sent via e-mail to the person who ordered the data set.

The In-situ Data Source Module Home Page resides at UCAR/JOSS at the following URL:

http://www.joss.ucar.edu/gcip/gcip_in_situ.html

It provides information on availability of various GCIP data sets, on-line documentation, links to WWW pages related to GCIP in-situ data, and an interactive electronic link to the CODIAC system. This link includes the ability to display specific data set information (metadata), a graphical display browse of user selected data, and WWW "forms" for the user to order data. All WWW displayed information is interactively extracted from the CODIAC database to ensure the information is up-to-date.

5.1.2 The Satellite Remote Sensing Data Source Module

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The GCIP Satellite Remote Sensing Data Source Module (SDSM) resides at the Global Hydrology Resource Center (GHRC) at the NASA/Marshall Space Flight Center (MSFC). The GHRC concentrates its data holdings in the discipline of the hydrologic cycle and currently contains mostly satellite-derived data sets. The GCIP SDSM at the GHRC coordinates and identifies data sets relevant to GCIP efforts such as the ESOP-95. Additionally, ESOP-95 users and data producers may contact the module with inquiries or additional requirements. The SDSM home page builds upon the available data and coordinating efforts. The SDSM home page is currently linked to the GCIP home page and the In-situ and Modeling Modules. The SDSM URL is:

http://ghrc.msfc.nasa.gov/gcip/sdsm.html

5.1.3 The Model Output Source Module

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The GCIP Model Output Source Module resides at the National Center for Atmospheric Research/Scientific Computing Division, Data Support Section. This module is the primary point of contact for the model output. The Model Output Source Module home page on the WWW at the following URL:

http://www.scd.ucar.edu/dss/pub/gcip/

The National Centers for Environmental Prediction (NCEP) (formerly the National Meteorological Center) has a GCIP home page that provides detailed information on the various Eta model output including the 3-D and 2-D fields as well as the MOLTS. It also provides information on retrieval of the model output. On-line data access is limited to the previous 24 hours of data. The WWW URL for the NCEP GCIP home page is:

http://nic.fb4.noaa.gov:8000/research/gcip.html

The Canadian Meteorological Centre (CMC) also has a GCIP home page that provides detailed information on the various RFE and GEM (Global Environmental Multiscale) model outputs. The WWW URL for the CMC GCIP home page is:

http://www.cmc.ec.gc.ca/cmc/CMOI/htmls/Gewex_archa.html

The NOAA/FSL has a home page that provides detailed information on the MAPS model. The WWW URL for the MAPS home page is:

http://maps.fsl.noaa.gov/gcip/maps_gcip.cgi

5.2 ESOP-95 CD-ROM

A subset of the data sets that are available through CODIAC have been published on a CD-ROM. Table 5-1 provides a summary of these data sets. Detailed descriptions of the data sets are provided in Section 3. Companion software tools are available to browse and display the data (i.e., areal plots, time series plots, altitude plots, image displays). These tools are available for PC, MacIntosh, and UNIX based systems. The CD-ROMs are available from JOSS and can be ordered via CODIAC.

A companion CD-ROM to GCIP has been produced by the USGS. This CD-ROM contains geographic information for the entire GCIP domain. Data sets contained on this CD-ROM are summarized in Table 5-2. Software to extract and view data have been included.

TABLE 5-1 ESOP-95 CD-ROM DATA SET CONTENTS

Surface Meteorological Data Sets

- ESOP-95 Hourly Surface Composite Data
- ESOP-95 20-Minute Surface Composite
- NCDC Cooperative Observer Network Data (Summary of the Day)
- NCDC SAO "Specials" Data

Precipitation Data Sets

- ESOP-95 15-min Precipitation Composite Data
- ESOP-95 Hourly Precipitation Composite Data
- ESOP-95 Daily Precipitation Composite Data
- ABRFC Miscellaneous Precipitation Data

Hydrology Data Sets

USGS Streamflow Data
USGS Reservoir Data

Images

ABRFC Stage III Daily Accumulated Precipitation Estimate Composites
Daily Eta Model 1200 UTC 1000 mb Synoptic Analyzed Map
Daily Eta Model 1200 UTC 850 mb Synoptic Analyzed Map
Daily Eta Model 1200 UTC 500 mb Synoptic Analyzed Map
Daily 1200 UTC GOES-7 4-km Infrared Satellite Image
Daily 2100 UTC GOES-7 2-km Visible Satellite Image
Daily 1200 UTC GOES-7 8-km Water Vapor Image
MSFC 1200 UTC National Precipitation Rate Composite
WSI 1200 UTC NOWRAD Composites
EROS Data Center Bi-weekly AVHRR Vegetation Composites

Upper Air

NWS high resolution (6-sec) soundings*
ARM/CART Soundings*
VORTEX Soundings*
NOAA Profiler Network Hourly Data (405 MHz)

Ancillary

Station List
Documentation
Tools

* Datasets are published in compressed format.

TABLE 5-2 Contents of USGS GCIP Reference Data Set (GREDS) CD-ROM

Meteorological and Hydrological Station Locations
Digital Elevation Model (DEM) at 500-m resolution
Geology of the Conterminous United States (1:2,500,000 scale)
Land Use of the Conterminous United States (1:7,500,000 scale)
Environmental Protection Agency (EPA) River Reach File for the Conterminous United States (Version 1)
Locations of Large Reservoirs of the United States
Average Annual Runoff in the Conterminous United States for 1951-1980 (1:7,500,000 scale)
Climatology of the United States, 1961-1990 (Normal Temperature, Precipitation, and Degree Days)
LANDSAT Nominal Row and Path Boundaries and Center Points (Index to LANDSAT Scenes)
Eta Model Grid Node Locations and description of Parameters
State and County Boundaries (1:2,000,000 scale)
USGS Quadrangle Map Index (1:250,000, 1:100,000, and 1:24,000 scales)
Hydrologic Unit Boundaries of the Conterminous United States (1:250,000 scale)
Listing of Long Term Climatological Stations
GIF Imagery of above Data sets (Browse purposes)
Miscellaneous Documentation of above Data Sets
Software and Source Code for Data Set Projection Translation

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APPENDIX A

ACRONYMS

ABRFC	Arkansas-Red Basin River Forecast Center
AES	Atmospheric Environment Service (Canada)
AERI	Atmospherically Emitted Radiance Interferometer
AFOS	Automated Field Operations and Services
ARESE	ARM Enhanced Shortwave Experiment
ARM	Atmospheric Radiation Measurements (DOE)
ARS	Agricultural Research Service (USDA)
ASCII	American Standard Code for Information Interchange
ASOS	Automated Surface Observing System
AVHRR	Advanced Very High Resolution Radiometer
AWOS	Automated Weather Observing System
BUFR	Binary Universal Format for data Representation
CART	Clouds and Radiation Testbed (DOE/ARM)
CD	Compact Disk
CLASS	Cross-chain Loran Atmospheric Sounding System
CLAVR	Clouds from AVhRr
CMC	Canadian Meteorological Centre
COAGMET	Colorado Agricultural Meteorology (Colorado State University)
COMET	Cooperative program for Operational Meteorology, Education, and Training (UCAR)
CSA	Continental Scale Area
CSIRO	Commonwealth Scientific and Industrial Research Organisation (Australia)
DAAC	Distributed Active Archive Center
DACOM	Data Collection and Management
DEM	Digital Elevation Model
DMSP	Defense Meteorological Satellite Program
DMSS	Data Management and Service System

DOE	Department of Energy
E	East
EDAS	Eta Data Assimilation System
EDC	EROS Data Center (USGS)
EOP	Enhanced Observing Period
EPA	Environmental Protection Agency
EROS	Earth Resources Observation Systems (USGS)
ESOP	Enhanced Seasonal Observing Period
FAA	Federal Aviation Administration
FAX	Facsimile
FEST	Fronts Experiment Systems Test (STORM)
FOS	Family of Services
FSL	Forecast Systems Laboratory (NOAA)
GAC	Global Area Coverage
GCIP	GEWEX Continental-scale International Project
GCM	Global Climate Model
GEM	Global Environmental Multiscale (CMC)
GEWEX	Global Energy and Water Cycle Experiment
GHCC	Global Hydrology and Climate Center (NASA/MSFC)
GHRC	Global Hydrology Resource Center (NASA/MSFC)
GIDS	GCIP Initial Data Sets
GIF	Graphic Image Format
GIST	GCIP Integrated Systems Test
GMS	Geostationary Meteorological Satellite (Japan)
GOES	Geostationary Operational Environmental Satellite
GREDS	GCIP Reference Data Set (USGS)
GRIB	GRId point values expressed in Binary form
GRL	Grazinglands Research Laboratory (USDA/ARS)
GSFC	Goddard Space Flight Center (NASA)
HDF	Hierarchical Data Format
HIRS	High Resolution Infrared Radiation Sounder
HPCN	High Plains Climate Network
HQC	Horizontal Quality Control

HRPT	High Resolution Picture Transmission
IBM	International Business Machines
ID	IDentification
IGPO	International GEWEX Project Office
IOP	Intensive Observation Period
IR	Infrared
ISA	Intermediate Scale Area
ISLSCP	International Satellite Land-Surface Climatology Project
JOSS	Joint Office for Science Support (UCAR)
LA	Limiting Angles
LAC	Local Area Coverage
LSA	Large Scale Area
MAPS	Mesoscale Analysis and Prediction System
METEOSAT	METEOrological SATellite (Europe)
MOLTS	Model Location Time Series
MORDS	Model Output Reduced Dataset
MSFC	Marshall Space Flight Center (NASA)
MSU	Microwave Sounding Unit
NASA	National Aeronautics and Space Administration
NAWDEX	NAtional Water Data Exchange (USGS)
NC	North Central
NCAR	National Center for Atmospheric Research
NCDC	National Climatic Data Center (NOAA)
NCEP	National Centers for Environmental Prediction (formerly NMC) (NOAA)
NESDIS	National Environmental Satellite, Data and Information Service (NOAA)
NEXRAD	NEXt generation RADar (now called WSR-88D)
NIDS	NEXRAD Information Dissemination Service
NMC	National Meteorological Center (presently NCEP) (NOAA)
NOAA	National Oceanic and Atmospheric Administration
NPN	NOAA Profiler Network
NSIDC	National Snow and Ice Data Center
NSSFC	National Severe Storms Forecast Center (presently SPC) (NOAA)
NSSL	National Severe Storms Laboratory (NOAA)

NW	North West
NWS	National Weather Service (NOAA)
NWSRFS	National Weather Service River Forecast System
OFPS	Office of Field Project Support (UCAR)
OH	Office of Hydrology (NOAA)
ORNL	Oak Ridge National Laboratory (DOE)
PBL	Planetary Boundary Layer
PC	Personal Computer
POES	Polar Orbiting Environmental Satellite
PSU	Pennsylvania State University
QC	Quality Control
RASS	Radio Acoustic Sounding System
RFC	River Forecast Center
RFE	Regional Finite Element
RISOP	Rapid Interval Scan Operations Plan
ROI	Radius of Influence
ROM	Read Only Memory
SAO	Surface Airways Observation
SBUV	Solar Backscattered Ultra Violet System
SCD	Scientific Computing Division (NCAR)
SCM	Single Column Model
SDSM	Satellite Data Source Module (GCIP)
SGP	Southern Great Plains
SLP	Sea Level Pressure
SMA	Soil Moisture Accounting
SMOS	Surface Meteorological Observation Station (DOE ARM)
SORTI	Solar Radiance Transmission Interferometer (DOE ARM)
SPC	Storm Prediction Center (formerly NSSFC) (NOAA)
SSA	Small Scale Area
SSEC	Space Science and Engineering Center (University of Wisconsin)
SSM/I	Special Sensor Microwave Imager
SSU	Stratospheric Sounding Unit
STATSGO	State Soil Geographic Database (USDA)

STORM	STorm-scale Operational and Research Meteorology
SW	South West
TIROS	Television and Infrared Observation Satellite
TOVS	TIROS Operational Vertical Sounder
UCAR	University Corporation for Atmospheric Research
URL	Uniform Resource Locator
USACE	United States Army Corps of Engineers
USAF	United States Air Force
USDA	United States Department of Agriculture
USGS	United States Geological Survey
USWRP	United States Weather Research Program
UTC	Universal Time Coordinated
UZFW	Upper Zone Free Water
VAD	Velocity Azimuth Display
VAS	VISSR Atmospheric Sounder
VDUC	VAS Data Utilization Center
VIS	Visible
VISSR	Visible and Infrared Spin-Scan Radiometer
VORTEX	Verification of the Origins of Rotation in Tornadoes EXperiment
WAVE	Weather-data and Assimilation Experiment (STORM)
WCRP	World Climate Research Programme
WMO	World Meteorological Organization
WPDN	Wind Profiler Demonstration Network
WSI	Weather Services International
WSR-88D	Weather Surveillance Radar - 1988 Doppler (formerly NEXRAD)
WV	Water Vapor
WWW	World Wide Web