# DRAFT

GLOBAL ENERGY AND WATER CYCLE EXPERIMENT (GEWEX)

CONTINENTAL-SCALE INTERNATIONAL PROJECT (GCIP)

# TACTICAL DATA COLLECTION AND MANAGEMENT PLAN for the LARGE-SCALE AREA NORTH WEST (LSA-NW; MISSOURI RIVER BASIN) ENHANCED ANNUAL OBSERVING PERIOD (EAOP)

## MARCH 1999

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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 objective of GCIP is to demonstrate skill in predicting changes in water resources on time scales up to seasonal and annual, as an integral part of the climate system. Within this overall goal, GCIP has set out the following science objectives: 1) Determine and explain the annual, interannual and spatial variability of the water and energy cycles within the Mississippi River basin; 2) Develop and evaluate coupled hydrologic/atmospheric models at resolutions appropriate to large-scale continental basins; 3) Develop and evaluate atmospheric, land, and coupled data assimilation schemes that incorporate both remote and in-situ observations; 4) Improve the utility of hydrologic predictions for water resources management up to seasonal and interannual time scales; and 5) Provide access to comprehensive in-situ, remote sensing, and model output data sets for use in GCIP research and as a benchmark for future studies (International GEWEX Project Office [IGPO] 1996b). The GCIP Enhanced Observing Period (EOP) 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 (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 ($3.2 \times 10^6$ km$^2$). These operate at a more or less steady level throughout the GCIP EOP.

**Large-scale area (LSA) activities** cover areas of about $10^5$ to $10^6$ km$^2$. 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 over concentrated regions to study a focused set of issues.

## 1.2 GCIP Data Sets

A summary of the GCIP data sets that have been, or will be, produced is depicted in Figure 1-2.

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-2 has not been developed due to funding constraints, possibilities for its future development are being discussed. 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-South West (LSA-SW) (see Figure 1-1). Complete information on the GIST data set is available from IGPO (1996a). GIDS-4 consists of data collected during the GCIP 1995 Enhanced Seasonal Observing Period (ESOP-95) which was also conducted in the LSA-SW (1 April - 30 September 1995). Complete information on the ESOP-95 data set is available from IGPO (1998). A GCIP Reference Data Set (GREDS) was completed in early 1995. The 17 different data sets (see Section 5.2) on this CD-ROM (Compact Disk-Read Only Memory) contain data that are expected to change little if any during the GCIP EOP period. Except for GIDS-2, each of the GIDS data sets has a CD-ROM available that includes a subset of the data available for that GIDS.

The first data set collected during the 5-yr EOP was the ESOP-96 which took place from 1 April to 30 September 1996 in the LSA-SW. The first data set collected outside of the LSA-SW was the ESOP-97 which took place from 1 October 1996 to 30 May 1997 in the LSA-North Central (LSA-NC). Also in the LSA-NC was ESOP-98 which took place from 1 October 1997 to 30 May 1998. The first data set collected in the LSA-East (LSA-E) was the 1998 Enhanced Annual Observing Period (EAOP-98) which took place from 1 October 1997 to 30 September 1998. Finally, the EAOP-99 also is taking place in the LSA-E. The data collection for EAOP-99 started 1 October 1998 and will continue through 30 September 1999. CD-ROMs may be compiled for each of these data sets.

Specific information about each data set is available on the World Wide Web (WWW) via the GCIP home page at the following URL (Uniform Resource Locator):

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

## 1.3 LSA-North West (LSA-NW) Enhanced Annual Observation Period (EAOP)

The LSA-NW EAOP will be conducted from 1 April 1999 to 30 March 2001 and will begin the observations in support of the LSA-NW focus as shown in Figure 1-1. A major objective for the LSA-NW EAOP is to contribute to a comprehensive data set for diagnostic, evaluation, and modeling studies and it is the first GCIP data set to have its focus in the LSA-NW.

The LSA-NW has several hydrometeorological features that are significant to GCIP. The LSA-NW has a large year-to-year variability in water cycle components, significant regulation of stream flow through dams, major orographic influences from the Rocky Mountains, relatively small runoff amounts, and significant snow measurement problems (including snowmelt timing with regard to water budget components). The LSA-NW also has a number of geographical and geological aspects that provide interesting hydrological features including

the Nebraska Sand Hills region, the High Plains and Madison aquifers provide extensive ground water transport regions, the topographically-closed potholes of the northern prairie wetlands, and extensive karst topography in both the western and eastern regions of the Missouri River basin. All of these features complicate the estimates of the basin-wide water budgets. Additionally, the LSA-NW encompasses some of the most heavily irrigated agricultural areas of North America, a feature whose impact on water and energy budgets is largely unknown (IGPO 1999).

The GCIP LSA-NW domain is shown in Figure 1-3. The geographical area extent of the Missouri River basin is defined as the irregular shaped polygon in Figure 1-3. For atmospheric modeling and other applications a more regular-shaped area is defined by the boundaries of $36^{o}$ to $51^{o}$ N latitude and $90^{o}$ to $115^{o}$ W longitude, and this is used as the latitude-longitude boundary for the LSA-NW. The meteorological and hydrological networks covering the Missouri River basin are less well developed than those of any previous LSAs, this is particularly true in the area of basin-wide surface energy and water vapor flux measurements.

### 1.4 Purposes of Document

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.

This document is entitled the Tactical Data Collection and Management Plan for the LSA-NW EAOP and is intended to serve two purposes:

(i) A summary of the approach to the data collection efforts during the period of 1 April 1999 through 30 March 2001 in lieu of an operations plan covering this period.

(ii) The data collected during the LSA-NW EAOP will provide the basis for the final data set from the 5-yr GCIP EOP and is the first GCIP data set located in the LSA-NW region. The LSA-NW EAOP will contain all of the same data types as were collected for previous GCIP LSAs. Enhancements from local networks will also be available for the LSA-NW EAOP.

The approach to the LSA-NW EAOP, a description of the data collected and how it will be disseminated are described in the remainder of this document.

# 2. OBJECTIVES AND APPROACH

The research objectives to be achieved from the LSA-NW data sets are described in the GCIP Major Activities Plan (IGPO 1999). The purpose of compiling the LSA-NW EAOP data set is to create the final data set during the GCIP 5-yr EOP which began in October 1995 and it will enable GCIP investigators to conduct focused studies (i.e. coupled model and diagnostic) unique to the LSA-NW during the year. The approach taken by the GCIP is to take the maximum advantage of the existing operational observing programs over the continental United States (US) while taking advantage of special collection of higher resolution data. Also, as additional improvements are made to the operational observing systems (i.e. the new satellite observing platforms that may become available during the LSA-NW EAOP period) they are incorporated.

The Missouri River basin offers several areas suitable for ISA and SSA studies. In the Upper Missouri River basin there are the Shortgrass Steppe Long Term Ecological Research (LTER) site, the Glacier National Park headwaters of the Missouri River, the Yellowstone River headwaters and Ft. Peck, Montana. The Shortgrass Steppe LTER is located in northeast Colorado (near Nunn) and is operated by researchers at Colorado State University (CSU) although researchers from several institutions conduct research on the site. The site includes an automated weather station, a United States Department of Agriculture (USDA) UVB (UltraViolet) radiation site,

soil moisture and temperatures measurements at one site, and a total of three flux towers (two operated by CSU and one by the USDA/Agricultural Research Service (ARS). Ft. Peck is located in northeast Montana and it has a National Oceanic and Atmospheric Administration (NOAA)/Air Resources Laboratory (ARL)/Surface Radiation Research Branch (SRRB) SURFRAD (Surface Radiation) site. There are also plans to place a NOSS long-term flux monitoring site nearby. A search for other data presently at/near this location found little other data available. Little is presently known on data collection at the Glacier National Park and the Yellowstone River locations.

In the Middle Missouri River basin there are the Black Hills region and the Sand Hills region. The Black Hills are located in southwestern South Dakota. There is an extensive network of precipitation gages, observational wells, and streamflow gages on the site. The US Geological Survey (USGS) is conducting the Black Hills Hydrology Study and the National Aeronautics and Space Administration (NASA) will be supporting a field program (Upper Missouri River Basin Pilot Project) in the region during the Spring of 1999. The Sand Hills are located in Nebraska. Investigations are still ongoing, but so far few significant data sources have been found to still be in existence.

In the Lower Missouri River basin there are the Konza Prairie Research Natural Area LTER site, Novelty Watershed Experiment Field, and Goodwater Creek. The Konza Prairie LTER site is located in northeastern Kansas near Manhattan and is operated by researchers at Kansas State University. Soil moisture and temperature measurements are taken at several locations on the site, there is one surface meteorological station, eleven precipitation stations, and one flux tower. At the Novelty watershed there are three separate watersheds instrumented since 1991 with flumes, flow level recorders and water samplers. There is also an automated weather station on site. At the Goodwater Creek site there are 15 (9) raingages during the warm (cold) season. There is also one automated weather station that also provides soil temperature and moisture measurements. Finally, there are also networks of glacial and alluvial aquifer well nests and piezometers.

The research hypothesis for the LSA-NW is that land-atmosphere interactions and terrain effects can be modeled with sufficient skill to provide useful predictions for hydrologic applications on daily to seasonal time scales. In an effort to test the validity of this hypothesis the LSA-NW planned research activities are divided into three components. First, land surface and hydrological characteristics which will be evolving from a static and coarse resolution representation of the land surface and hydrological characteristics to a more detailed and dynamic landscape characterized by a strong annual cycle with significant spatial and temporal variability. Second, coupled hydrologic/atmospheric modeling will diagnose and skillfully represent the significant regional effects of land/atmosphere interactions on the hydrometeorology and hydroclimate of the Missouri River basin on spatial and temporal scales relevant for hydrologic applications and water resources. Finally, hydrometeorological prediction and water resources will enhance the reliability of precipitation, streamflow and related hydrologic variables that impact the water supply and demand forecasts for water managers in temporal scales up to seasonal (IGPO 1999).

In summary, the LSA-NW EAOP will provide a data set that: (1) includes atmospheric and hydrological data obtained in a major river basin; (2) includes a complete hydrologic cycle in a region with complex terrain; (3) includes routine operational data as well as special research observing platforms combined for a two year period; and (4) provides quality controlled surface and upper air composite data sets as required by the GCIP EOP.

# 3. DATA SOURCES AND COLLECTION

The LSA-NW EAOP data can be divided into three major data categories: *In situ*, satellite, and model. The responsibility in data collection will fall under each module of the GCIP Data Management and Service System (DMSS). Although most of the data sources are operational in nature, special arrangements will be made to obtain these data in the resolution required by GCIP. Table 3-1 summarizes the individual potential data sets comprising the LSA-NW EAOP. 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 and in Appendix A. Information on data set dissemination is provided in Section 5. As this is a planning document, not all data sets described herein may be collected.

Conversely, additional data sets may be discovered at a later date and added. In particular, the Plan was put together with the latitude/longitude box (see Figure 1-3) in mind, but based on input from the GCIP Data Collection and Management (DACOM) Committee the focus for data collection will be on networks that at least partially fall within the Missouri River basin itself (see Figure 1-3). Thus state specific data sets from Idaho, Illinois, Minnesota, Utah and Wisconsin will not be collected. Additionally data from the Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) Cloud and Radiation Testbed (CART) Southern Great Plains (SGP) site will not be collected. Information on the final LSA-NW EAOP data sets will be provided in the LSA-NW EAOP Tactical Data Collection and Management Report to be published after the data collection phase of the LSA-NW EAOP is complete.

**Table 3-1 Preliminary Data Set Summary for the LSA-NW EAOP**

***IN-SITU* DATA**

Surface Data

National

- AmeriFlux Network Data
- Automated Surface Observing System (ASOS) Data
- Automated Weather Observing System (AWOS) Data
- Canadian Surface Observation Data
- Long Term Ecological Research (LTER) Network Data
- National Atmospheric Deposition Program/National Trends Network Data
- NOAA/National Centers for Environmental Prediction (NCEP) Precipitation Data
- NOAA Profiler Network (NPN) Surface Data
- National Weather Service (NWS) Cooperative Observer Daily Observation Data
- NWS Cooperative Observer Precipitation Data
- Remote Automatic Weather Station (RAWS) Network Data
- Surface Airways Observations (SAO) Hourly Data
- SAO Special Observation Data
- Surface Radiation (SURFRAD) Network Data
- US Army Corps of Engineer (USACE) Precipitation and Streamflow Data
- USDA UVB Radiation Monitoring Network Data
- USDA Natural Resources Conservation Service (NRCS) Soil Moisture/Soil Temperature (SM/ST) Network Data
- USDA/NRCS Snow Course Survey Data
- USDA/NRCS Snow Data Telemetry System (SNOTEL) Network Data
- USDA/ARS Research Site Data
- US Environmental Protection Agency (EPA) Aerometric Information Retrieval System (AIRS) Network Data
- USGS Reservoir Data
- USGS Reservoir Data from Cooperative Agencies
- USGS Streamflow Network Data

Regional

- DOE ARM SGP CART Eddy Correlation (ECOR) Data
- DOE ARM SGP CART Energy Balance Bowen Ratio (EBBR) Data
- DOE ARM SGP CART Soil Water and Temperature System (SWATS) Data
- DOE ARM SGP CART Solar Infrared Radiation Station (SIRS) Data
- DOE ARM SGP CART Surface Meteorological Observation System (SMOS) Data
- High Plains Climate Network (HPCN) Data
- Management Systems Evaluation Areas (MSEA) Project Data
- US Bureau of Reclamation (USBR) AgriMet Network Data
- USGS/Scientific Assessment and Strategy Team (SAST) Data
- USGS Mississippi Basin Carbon Project Data
- Wisconsin and Illinois Gravediggers Network Data

Colorado
- Colorado Agricultural Meteorological (CoAgMet) Network Data
- Denver Urban Drainage and Flood Control District ALERT Data

Idaho
- NOAA/ARL/Field Research Division (FRD) Southern Idaho Tower Network Data
- USDA/ARS Reynolds Creek Experimental Watershed Data

Illinois
- Cook County Precipitation Network Data
- Illinois Climate Network (ICN) Data
- Illinois Department of Transportation (DOT) Network Data
- Illinois State Water Survey (ISWS) Soil Moisture Monitoring Network Data
- ISWS Shallow and Deepr Ground-Water Observation Wells Data
- Imperial Valley Water Authority Precipitation Network Data

Iowa
- Davenport ALERT Network Data
- Iowa State University (ISU) Soil Moisture Survey Data
- National Soil Tilth Laboratory (NSTL) Walnut Creek Watershed Energy Balanceand Evapotranspiration Network Data
- NSTL Walnut Creek Watershed Meteorological Station Data
- NSTL Walnut Creek Watershed Precipitation Network Data
- NSTL Walnut Creek Watershed Surface and Groundwater Data

Kansas
- Overland Park ALERT Network Data

Minnesota
- Minnesota Department of Natural Resources (DNR) Fire Weather Network (FWN) Data
- Minnesota DOT Network Data
- Minnesota Road Research Project (Mn/ROAD) Data
- USGS Interdisciplinary Research Initiative (IRI) Site Data
- University of Minnesota (UM) Experiment Station Data
- UM Extension Climatology Network Data

Missouri
- Goodwater Creek Area Data
- Missouri Commercial Agriculture Weather Station (CAWS) Network Data
- Missouri Department of Conservation (DOC) FWN Data
- Novelty Watershed Experiment Field Data

Montana
- Glacier National Park Field Station Data
- Montana DOT Network Data
- Northwest Montana ALERT Network Data

Nebraska
- Papio Basin ALERT Network Data
- Sand Hills Region Data

North Dakota
- Grand Forks Air Force Base Network Data
- North Dakota Atmospheric Resources Board (NDARB) Cooperative Rain Gage Network Data

South Dakota
- Black Hills Hydrology Study Data
- Upper Missouri River Basin Pilot Project Data

Utah
- Tooele Army Depot Network Data
- US Army Dugway Proving Grounds Network Data
- Utah DOT Network Data

Wisconsin

USDA/NRCS Wisconsin Dense Till (WDT) Data
University of Wisconsin (UW) Agricultural Weather Observation Network (AWON) Data
Wisconsin DNR FWN Data
Wisconsin DOT Network Data

Wyoming

Greater Yellowstone Experiment Data
Wyoming DOT Network Data

JOSS LSA-NW EAOP Composite Data Sets

Hourly Surface Composite
Hourly Precipitation Composite
Daily Precipitation Composite

Upper Air Data

DOE ARM SGP CART Microwave Radiometer (MWR) Data
DOE ARM SGP CART Sounding Network Data
DOE ARM SGP CART AERI Data
DOE ARM SGP CART Boundary Layer Profiler Data
DOE ARM SGP CART 60 m Tower Data
DOE ARM SGP CART Vaisala Ceilometer Data
NWS Upper Air Rawinsonde Data (6-sec vertical levels)
NWS Upper Air Rawinsonde Data (mandatory/significant levels)
Canadian Upper Air Rawinsonde Data (10-sec vertical levels)
Canadian Upper Air Rawinsonde Data (mandatory/significant levels)
NPN Data
Boundary Layer Profiler Data

Radar Data

WSR-88D Data
WSR-88D NIDS Data
WSI Reflectivity Composite Imagery
NASA/MSFC National Reflectivity Composite
NCEP National Precipitation Analysis Data
NOAA/RFC Stage III WSR-88D Data

Land Characterization Data

PSU 1-km Multi-Layer Soil Characteristics Data Set
Earth Resources Observation Systems (EROS) Data Center (EDC) Bi-Weekly Vegetation Index Data
EDC Global Land 1 km AVHRR Data
EDC Global 30 Arc Second Elevation Data
EDC Hydro 1-k Elevation Derivative Data

**SATELLITE DATA**

Operational Satellite Data
NOAA Airborne Gamma Snow Survey Data
Future Satellite Data

**MODEL OUTPUT**

AES/CMC GEM Model Output
NOAA/FSL MAPS Model Output
NOAA/NCEP Eta Model Output

NOAA/NCEP Eta Model 12 UTC Initial Analysis GIF Imagery
MOLTS Output
MOLTS Derived Sounding Output
MORDS Output

## 3.1 *In-situ* Data

The following *in-situ* data sets may be collected, processed, quality assured, archived, and disseminated at the *In-Situ* Data Source Module [University Corporation for Atmospheric Research (UCAR)/Joint Office for Science Support (JOSS)]. Data set details are provided in the following subsections. Information on data and metadata retrieval is provided in Section 5.

### 3.1.1 Surface Data

Ameriflux Network Data - Ameriflux is a network of sites conducting long-term measurements of $CO_2$, water and energy fluxes. There are six Ameriflux locations within the LSA-NW (Figure 3-1). The surface meteorological and precipitation data from the Ameriflux sites will be merged, quality controlled, and archived at the JOSS. These data will be made available from JOSS as part of the Hourly Surface, Hourly Precipitation and Daily Precipitation Composites. The non-surface meteorological and precipitation data will be made available from JOSS in separate data sets. The Ameriflux sites within the LSA-NW include:

*Colorado* - This site is operated by researchers at the University of Colorado and the National Center for Atmospheric Research (NCAR) on the Niwot Ridge (3050 m elevation) LTER site west of Boulder, Colorado. It is in a subalpine forest ecosystem with Engehamm spruce, lodgepole pine, subalpine fir, and some aspen. There are two towers on site that collect hourly $CO_2$ flux, heat flux, $O_3$ and $NO_x$ deposition, isoprene, monoterpenes, methylbutenol flux, soil, leaf, stem respiration, radiation balance above canopy and surface stability, wind profiles, and drainage flow loss of trace gasses (using the second tower). Some ancillary measurements include living and dead above ground biomass, canopy light and temperature environment, leaf area index, leaf photosynthesis, leaf and branch hydrocarbon emission, and soil $CO_2$ fluxes and hydrocarbon measurements using micromet techniques.

*Kansas* - This site is operated by researchers at Kansas State University and is located on the Konza prairie LTER site near Manhattan, Kansas. The core measurements taken at the site include net CO, and water vapor flux, bowen ratio and surface energy balance, and soil respiration. Other measurements taken continuously include friction velocity, momentum transport, wind speed and direction, air temperature, soil temperature, canopy temperature, vapor pressure, CO, concentration, global irradiance, net radiation, Photosynthetically Active Radiation (PAR), soil heat flux, barometric pressure, and precipitation. Measurements taken periodically include soil-surface CO, flux, leaf area index, biomass, soil water content, leaf photosynthesis, and stomatal conductance.

*Oklahoma* - These sites are operated by researchers from the University of Nebraska, Lincoln and the Carnegie Institution of Washington. One tower is in a tallgrass prairie site near Shidler, Oklahoma and the other is a wheat site near Ponca City, Oklahoma. The core measurements taken at these sites include eddy fluxes of carbon dioxide, water vapor, sensible heat and momentum; soil heat flux and soil temperature; mean wind speed, air temperature, humidity and carbon dioxide concentration; precipitation; and global, net and photosynthetically active radiation. Ancillary measurements taken at the sites include soil moisture, leaf area index, canopy height, biomass and leaf nitrogen content.

*Wisconsin* - This site is operated by researchers at NOAA/Climate Monitoring and Diagnostics Laboratory (CMDL), the University of Minnesota, and the US Forest Service (USFS) near Park Falls and the Chequamegon National Forest in north central Wisconsin. The measurements taken on the tower include $CO_2$ and water fluxes at 30, 122, and 396 m above the ground, $CO_2$ mixing ratios at 11, 30, 76, 122, 244, and 396 m above ground,

CO, $CH_4$, H,, N,O, and $SF_6$ halcarbon mixing ratios at 30, 76, and 396 m, net radiation, PAR, surface pressure, and precipitation. There is also a USFS site nearby (Willow Springs) that collects measurements including canopy microclimate, soil temperature, soil moisture, precipitation, snow depth, and PAR.

*Wyoming* - This site is operated by researchers at the USFS in south central Wyoming near Medicine Bow. It is in a subalpine/alpine region at 3186 m elevation. It is in an Engelmann spruce, subalpine fir, forested ecosystem. The data collected includes half-hourly measurements of $CO_2$ flux, latent heat flux, heat flux, momentum flux, PAR, net radiation, incoming and outgoing long and shortwave radiation, soil heat flux, temperature, wind speed, wind direction, relative humidity and ambient pressure. Some additional ancillary measurements include biomass, cover, canopy height, canopy roughness, clumping, and leaf area index.

Automated Surface Observing System (ASOS) Data - These data include hourly 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 are available at 204 sites (including both commissioned and uncommissioned sites) within the LSA-NW (Figure 3-2). Data will be merged, quality controlled, and archived at the JOSS. These data will be made available from JOSS as part of the Hourly Surface, Hourly Precipitation and Daily Precipitation Composites. 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 data from the Federal Aviation Administration (FAA) AWOS stations as well as networks operated by various non-federal agencies. These data include 20-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 are available at 154 sites within the LSA-NW (Figure 3-3). Data will be merged, quality controlled, and archived at the JOSS. These data will be made available from JOSS as part of the Hourly Surface, Hourly Precipitation and Daily Precipitation Composites.

Canadian Surface Observation Data - This data will include any available Canadian surface observations as collected at NOAA/National Climatic Data Center (NCDC). There are 20 sites within the LSA-NW (Figure 3-4). Data will be merged, quality controlled, and archived at the JOSS. These data will be made available from JOSS as part of the Hourly Surface, Hourly Precipitation and Daily Precipitation Composites.

Long Term Ecological Research (LTER) Network Data - The LTER is a network is set up to allow investigation of ecological processes at long time scales and over broad spatial scales. There are four LTER network sites within the LSA-NW Figure 3-5). The surface meteorological and precipitation data from the LTER sites will be merged, quality controlled, and archived at the JOSS. These data will be made available from JOSS as part of the Hourly Surface, Hourly Precipitation and Daily Precipitation Composites. The non-surface meteorological and precipitation data will be made available from JOSS in separate data sets. The LTER sites within the LSA-NW include:

*Cedar Creek Natural History Area LTER* - The Cedar Creek Natural History Area LTER is operated by researchers at the University of Minnesota about 50 km north of Minneapolis in Bethel, Minnesota. There is one automated weather station at this site and it is part of the Minnesota Extension Climatology Network. Significant amounts of data relating to ecosystem functioning are also collected at the site.

*Konza Prairie Research Natural Area LTER* - The Konza Prairie Research Natural Area LTER is operated by researchers at Kansas State University in northeastern Kansas about 10 km south of Manhattan, Kansas. The measurements taken at the site include soil moisture every two weeks during the warm season and monthly during the cold season at approximately six sites. It is taken with a neutron probe at 25, 50, 75, 100, 125, 150, 175 and 200 cm and measurements started in 1983. Also soil temperature at four sites at 2, 10 and 25 cm at hourly intervals starting in 1987. There is one surface meteorological station with hourly temperature, relative humidity, wind speed and direction, solar radiation, precipitation, and soil temperature at 25 cm. There are also

11 precipitation stations with some providing hourly data and the others daily, all but two of these are warm season only. Also, the soil bulk density and chemical characteristics have been measured at most of the plots. Additionally there is a flux tower located on the site, this was described above under the Ameriflux network data.

*Niwot Ridge/Green Lake Valley LTER* - The Niwot Ridge/Green Lake Valley LTER is operated by researchers at the University of Colorado in north central Colorado in the Rocky Mountains west of Boulder, Colorado. There are seven automated meteorological stations on the site at various elevations and locations relative to the ridge, the measurements taken vary by site but can include air temperature, precipitation, solar radiation, relative humidity, evapotranspiration, wind speed and direction, snow water equivalence and barometric pressure. In the past there have been flux measurements taken during the short growing season, but these are not currently going on. There are occasional snow ablation and snow survey measurements taken. Time Domain Reflectometry (TDR) and gravimetric soil moisture measurements are also taken occasionally. Streamflow measurements are available at three locations. Primary production, biomass and other plant phenology measurements are also available.

*Shortgrass Steppe LTER* - The Shortgrass Steppe LTER is operated by researchers at CSU in northeastern Colorado near Nunn. There is one automated weather station on the site collecting hourly values including solar radiation and year-round precipitation. There is a USDA UVB radiation site. Soil moisture is measured hourly at one location on the site using a lysimeter. Soil temperature is measured hourly at one location on the site at 2.5, 5, 10 and 20 cm depths. There are also two flux towers on the site operated by Colorado State University one in irrigated corn and the other in wheat fallow. Additionally the USDA/ARS operates a flux tower in the shortgrass steppe. These towers collect 20 min averages of carbon dioxide, water vapor, and temperature differences at two heights (vary depending on the tower location), air temperature, net radiation, wind speed and direction, soil moisture (2.5 cm), soil heat flux (8 cm), soil thermocouples (2 and 6 cm) and precipitation.

National Atmospheric Deposition Program/National Trends Network (NADP/NTN) Data - The NADP/NTN is a nationwide network of 280 precipitation monitoring stations. Daily precipitation observations, weekly precipitation chemistry, and monthly, seasonal and annual precipitation-weighted mean concentration observations are taken. Within the LSA-NW there are 84 locations (Figure 3-6). Data for the LSA-NW EAOP period may be extracted and forwarded to the JOSS. Data may be merged, quality controlled, and archived at the JOSS. These data may be made available from JOSS as part of the Daily Precipitation Composites.

NOAA/National Centers for Environmental Prediction (NCEP) Precipitation Data - These data include precipitation observations from various stations across the US. The frequency of the observations varies from 15 min to hourly to stations that collect data with no set schedule. No map is available. These data are collected by the NOAA River Forecast Centers (RFC) and sent to NCEP. Data for the LSA-NW EAOP period will be extracted and forwarded to JOSS. Data will be merged, quality controlled and archived at JOSS. These data will be made available from JOSS as part of the Hourly and Daily Precipitation Composites.

NOAA Profiler Network (NPN) Surface Data - The NPN routinely record hourly and 6-minute surface observations of temperature, dew point, station pressure, precipitation amount, wind speed, and wind direction at 7 of its 20 405 MHz profiler sites in the LSA-NW (Figure 3-7). The data are routinely collected and processed by NOAA/Forecast Systems Laboratory (FSL) and archived at NOAA/NCDC. Data for the LSA-NW EAOP period will be extracted and forwarded to the JOSS. Data will be merged, quality controlled, and archived at the JOSS. These data will be made available from JOSS as part of the Hourly Surface, Hourly Precipitation and Daily Precipitation Composites.

National Weather Service (NWS) Cooperative Observer Daily Observation Data - The NOAA/NWS routinely records daily observations of maximum and minimum temperature, precipitation, snowfall and snow depth. Some sites also record daily observations of evaporation and soil temperature. These sites are operated by cooperative observers over the conterminous U and are processed and archived by NOAA/NCDC. Data for the 3583 stations within the LSA-NW (Figure 3-8) will be extracted and forwarded to the JOSS. Data will be merged, quality controlled, and archived at the JOSS. These data will be made available from JOSS as part of the Daily Precipitation Composite.

NWS Cooperative Observer Precipitation Data - The NOAA/NWS routinely collects 15-minute or hourly observations of precipitation from Fisher-Porter and Universal rain gages operated by cooperative observers over the conterminous US. In the LSA-NW there are 868 sites (Figure 3-9). These data are processed and archived by NOAA/NCDC. Data for the LSA-NW EAOP period will be extracted and forwarded to the JOSS. Data will be merged, quality controlled, and archived at the JOSS. These data will be made available from JOSS as part of the Hourly Precipitation and Daily Precipitation Composites.

Remote Automatic Weather Station (RAWS) Network Data - This network is overseen by the USFS, but the stations are maintained and operated by various federal and state agencies. There primary application is in fire weather forecasting, and most stations are located in or near forested locations. There are 255 stations within the LSA-NW (Figure 3-10). Most of the sites use the Forest Technology Systems (FTS), Incorporated automated stations and archive hourly observations of air temperature, relative humidity, wind speed, wind direction, and precipitation. Data will be merged, quality controlled, and archived at the JOSS. These data will be made available from JOSS as part of the Hourly Surface, Hourly Precipitation 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 are routinely recorded at approximately 130 sites within the LSA-NW (Figure 3-11); there are others in the northern and western portions of the LSA-NW, but do not have a station list for them) and will be processed and archived at NCDC. Data for the LSA-NW EAOP period will be extracted and forwarded to the JOSS. Data will be merged, quality controlled, and archived at the JOSS. These data will be made available from JOSS as part of the Hourly Surface, Hourly Precipitation 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 US Department of Commerce (1988). Data are routinely recorded at 130 sites within the LSA-NW (Figure 3-11) and will be processed and archived at NCDC. Data for the LSA-NW EAOP period will be extracted and forwarded to the JOSS. These data will be made available from JOSS as a separate data set.

Surface Radiation (SURFRAD) Network Data - The NOAA ARL/SRRB operates the Surface Radiation Budget Network (SURFRAD) which has six locations over the US. Within the LSA-NW there two stations, one at Boulder, Colorado and the other at Ft. Peck, Montana (Figure 3-12). The Boulder site is located on the NOAA/SRRB Table Mountain Test Facility about eight miles north of Boulder. The Ft. Peck site is located on the Fort Peck Tribes Reservation about 15 miles north of Poplar, Montana. Measurements include direct solar radiation via a normal incidence pyrheliometer, downwelling global solar radiation via an upward-viewing broadband pyranometer, solar radiation reflected from the surface via a downward-viewing broadband pyranometer, thermal infrared (IR) emitted downward via an upward-viewing pyrgeometer, upwelling thermal radiation from the surface via a downward-viewing pyrgeometer, ultraviolet radiation at the surface via a UVB radiometer, and global and diffuse solar radiation in one broadband channel and six narrow bands of the solar spectrum via a Multi-Filter Rotating Shadowband Radiometer (MFRSR). Also on site are instruments to measure wind speed, wind direction, air temperature, relative humidity, and station pressure at the top of a 10 m tower.

US Army Corps of Engineer (USACE) Precipitation and Streamflow Data - These data include hourly observations of precipitation and daily observationa of streamflow from USACE operational gages. The number of stations located within the LSA-NW is not yet known. These data are included within the USGS streamflow data set. The precipitation data will be merged, quality controlled, and archived at the JOSS. These data will be made available from JOSS as part of the Hourly Precipitation and Daily Precipitation Composites. The streamflow portion of the data will be included as a separate data set with the USGS streamflow data.

USDA UVB Radiation Monitoring Network Data - The USDA operates a network of 25 UVB monitoring stations over the US and Canada. Seven of these stations are within the LSA-NW (Figure 3-13). Measurements of total horizontal, direct, normal and diffuse solar irradiance at 13 wavelengths (using VIS and UV MFRSR);

global UVB irradiance (using a broadband UVB-1 pyranometer); surface reflectance (using a downward looking photometer); and temperature and relative humidity. The data are archived by the USDA UVB Radiation Monitoring Program at Colorado State University.

USDA/Natural Resource Conservation Service (NRCS) Soil Moisture/Soil Temperature (SM/ST) Network Data - The NRCS operates the SM/ST Pilot Project as a preliminary effort to set up a network of soil climate sites throughout the US and consists of 28 sites. Six of these are within the LSA-NW (Figure 3-14). Measurements at each site include soil moisture and soil temperature at six depths (2, 4, 8, 20, 40, and 80 inches). Also, air temperature, relative humidity, wind speed, wind direction, solar radiation, and precipitation are measured at each site. The soil moisture is measured via two types of electrical resistance blocks at each depth. The soil at each site has been sampled and characterized, including soil bulk density and soil water retention curves for each horizon. Measurements are usually recorded every hour. Data are archived by NRCS in Portland, Oregon. The data are uncalibrated, uncorrected, and preliminary; thus they are subject to revision. The data for the LSA-NW EAOP period will be extracted by JOSS. The surface meteorological and precipitation data will be merged, quality controlled, and archived at the JOSS. These data will be made available from JOSS as part of the Hourly Surface, Hourly Precipitation and Daily Precipitation Composites. The other data will be made available from JOSS as a separate data set.

USDA/NRCS Snow Course Survey Data - The NRCS typically takes monthly snow course measurements at a variety of locations over the mountains of the western US. Snow depth is measured and snow water equivalent is estimated. The data for the LSA-NW EAOP period will be extracted by JOSS. The data will be made available from JOSS as a separate data set.

USDA/NRCS Snow Data Telemetry System (SNOTEL) Network Data - The NRCS operates the SNOTEL network primarily over the mountains of the western US. Measurements available at each site include liquid equivalent precipitation, snow water content (using snow pillows) and air temperature typically at hourly intervals. Within the LSA-NW there are 373 SNOTEL sites (Figure 3-15). The data for the LSA-NW EAOP period will be extracted by JOSS. The surface meteorological and precipitation data will be merged, quality controlled, and archived at the JOSS. These data will be made available from JOSS as part of the Hourly Surface, Hourly Precipitation and Daily Precipitation Composites. The other data will be made available from JOSS as a separate data set.

USDA/ARS Research Site Data - Although there are 11 USDA/ARS research stations within the Missouri River basin region (including in Akron and Fort Collins, Colorado; Manhattan, Kansas; Miles City and Sidney, Montana; Clay Center and Lincoln, Nebraska; Mandan, North Dakota; Brookings, South Dakota; and Cheyenne and Laramie, Wyoming) the data collection efforts related to GCIP goals are limited. If any data of interest to GCIP is discovered it may be gathered by JOSS.

US Environmental Protection Agency (EPA) Aerometric Information Retrieval System (AIRS) Network Data - This network is overseen by the US EPA, but the stations are maintained and operated by the state environmental protection agencies as well as some industrial organizations. Their primary purpose is pollutant regulation, and most stations are located near large cities and pollutant sources. All sites collect hourly observations of wind speed and direction, many sites collect temperature, a few sites collect relative humidity, barometric pressure and precipitation. There are 254 stations within the LSA-NW (Figure 3-16). Data will be merged, quality controlled, and archived at the JOSS. These data will be made available from JOSS as part of the Hourly Surface, Hourly Precipitation and Daily Precipitation Composites.

USGS Reservoir Data - These data include daily observations of reservoir contents or water level for 788 reservoirs within the LSA-NW (Figure 3-17). All data (data may not be collected by USGS for all sites) are available through the USGS Office in Reston, Virginia as well as the USGS district offices. Data for LSA-NW EAOP period will be extracted and forwarded to the JOSS. These data will be made available from JOSS as a separate data set.

USGS Reservoir Data from Cooperative Agencies -These data include monthly observations of reservoir contents or water level for an as yet unknown number of reservoirs within the LSA-NW. These data were

collected by a variety of agencies and were gathered and archived by the USGS. Data for the LSA-NW EAOP period will be extracted and forwarded to JOSS. These data will be made available from JOSS as a separate data set.

USGS Streamflow Network Data - These data consist of determinations of daily-mean streamflow at USGS gages. The basic data consist of hourly or more frequent direct observations of stage (water level), from which discharge (flow) is computed using a stage-discharge rating relation. The rating is defined by occasional (about 6-9 per year) direct current-meter measurements of discharge. A total of 2119 streamflow-gaging stations (Figure 3-18) are located within the LSA-NW. All data are available through the USGS Office of Surface Water in Reston, Virginia as well as the district offices in each state. Provisional (preliminary) data for about half of these stations are transmitted in near-real time via the GOES satellite and posted on the WWW (http://water.usgs.gov). These provisional data receive minimal quality control and remain accessible for one week. These data are available to the public and can be retrieved as needed by individual investigators; GCIP does not plan to collect these provisional data. Final quality-assured streamflow data are released to the public by the USGS annually about nine months after the end of the water year (which ends on 30 September). The final daily-mean discharge data are available in printed data reports as well as on the WWW. Final daily-mean streamflow data for the LSA-NW EAOP will be extracted and forwarded to JOSS. *NOTE - The streamflow data generally represent actual observed flows; they generally are not adjusted ("naturalized") to remove effects of diversions or reservoir storage. CAUTION - The preliminary streamflow data are subject to reprocessing and substantial revision until they are formalized and published about nine months after the end of the water year (1 October - 30 September). The preliminary data are furnished in the interest of free and timely information exchange, but it must be remembered that they represent work in progress. Substantial revisions may be required because of malfunctions of sensing and recording equipment or because of physical changes in the relation between measured water level (stage) and discharge. These changes may be caused by accumulation or break-up of debris jams or winter ice, by growth or decay of aquatic vegetation, or by erosion or deposition of sediments in the stream channel. Preliminary streamflow data for periods of severe ice effects may bear little relation to actual flows. Data users are cautioned to consider carefully the provisional nature of the information before using it for decisions that concern personal or public safety or the conduct of business that involves substantial monetary or operational consequences.*

DOE ARM SGP CART Eddy Correlation (ECOR) Data - The DOE ARM program operates a network of ECOR systems at its SGP CART site that provide measurements of the surface momentum and latent and sensible heat fluxes. ECOR systems are operational at eight of the ARM extended facilities located in either wheat or alfalfa crops or pasture. Additionally at least two other ECOR systems may come on-line during the LSA-NW EAOP. Eight of the current and future ECOR systems are within the LSA-NW (Figure 3-19). The data are collected and processed by the DOE ARM Program and are archived at DOE Oak Ridge National Laboratory (ORNL).

DOE ARM SGP CART Energy Balance Bowen Ratio (EBBR) Data - The DOE ARM program operates a network of EBBR systems at its SGP site that provide measurements of sensible and latent heat fluxes. EBBR systems are operational at 13 of the ARM extended facilities over a variety of land surface conditions (crops, pasture, rangeland and prairie). At least one additional EBBR system may come on-line during the LSA-NW EAOP. The EBBR systems (except for one) are located at different extended facilities than the ECOR systems. Eight of the current and future EBBR systems are within the LSA-NW (Figure 3-19). The data are collected and processed by the DOE ARM Program and are archived at DOE ORNL.

DOE ARM SGP CART Soil Water and Temperature System (SWATS) Data - The DOE ARM program operates a network of SWATS systems at its SGP site that provide soil moisture and temperature measurements at eight depths: 5, 15, 25, 35, 60, 85, 125 and 175 cm. Campbell Scientific heat dissipation soil moiisture sensors are used. Each site has two profiles located one meter apart. SWATS systems are operational at 20 of the ARM extended facilities. At least two additional SWATS systems may come on-line during the LSA-NW EAOP. Fifteen of the current and future SWATS systems are within the LSA-NW (Figure 3-19). The data are collected and processed by the DOE ARM Program and are archived at DOE ORNL.

DOE ARM SGP CART Solar Infrared Radiation Station (SIRS) Data - The DOE ARM program operates a network of SIRS (formerly the Solar and Infrared Radiation Observing System [SIROS]) systems at its SGP site

that provide measurements of up and down-welling hemispherical solar irradiances, direct-beam solar irradiance, diffuse hemispherical solar irradiance from the sky and up- and down-welling hemispherical infrared irradiances via its collection of instruments including the MFRSR, pyranometers and pyrgeometers. SIRS systems are operational at 20 of the ARM extended facilities. At least two additional SIRS systems may come on-line during the LSA-NW EAOP. Fifteen of the current and future SIRS systems are within the LSA-NW (Figure 3-19; same locations as SWATS). The data are collected and processed by the DOE ARM Program and are archived at DOE ORNL.

DOE ARM SGP CART Surface Meteorological Observation Stations (SMOS) Data - The DOE ARM program operates a network of SMOS systems at its SGP site that provide one-minute observations of air temperature, relative humidity, wind speed and direction, barometric pressure, precipitation and snow depth. SMOS systems are operational at 14 of the ARM extended facilities. At least one additional SMOS system may come on-line during the LSA-NW EAOP. Eleven of the current and future SMOS systems are within the LSA-NW (Figure 3-19; similar to SWATS, but fewer sites). The data are collected and processed by the DOE ARM Program and are archived at DOE ORNL. Data for the LSA-NW EAOP period will be extracted and forwarded to JOSS. Data will be merged, quality controlled, and archived at the JOSS. These data will be made available from JOSS as part of the Hourly Surface, Hourly Precipitation and Daily Precipitation Composites.

High Plains Climate Network (HPCN) Data - The HPCN is a network of stations over the High Plains of the US that is actually a collection of a group of smaller state climatologist operated networks. Measurements available include hourly observations of temperature, dew point, precipitation amount (during the warm season only), wind speed and direction. Soil moisture measurements are also available at some locations on either weekly or biweekly intervals. There are 141 HPCN sites within the LSA-NW (Figure 3-20). The data are collected, processed, and archived by the High Plains Regional Climate Center at the University of Nebraska, Lincoln. Data for the LSA-NW EAOP period will be extracted and forwarded to JOSS. Data will be merged, quality controlled, and archived at the JOSS. These data will be made available from JOSS as part of the Hourly Surface, Hourly Precipitation and Daily Precipitation Composites.

Management Systems Evaluation Areas (MSEA) Project Data - MSEA is a multi-agency program looking at agricultural chemicals and water quality. There are seven MSEA research location within the LSA-NW (Figure 3-21). Only four of the locations have an automated weather station on site. These stations provide hourly averages of temperature, relative humidity, wind speed, and wind direction. Also hourly precipitation is recorded via a tipping bucket raingage and soil temperatures are recorded down to 1 m. Some of the sites may be collecting soil moisture measurements. JOSS will attempt to get data from the MSEA sites, but has not been able to in the past. If JOSS is able to get data from these sites it will be merged, quality controlled, and archived at the JOSS. These data will be made available from JOSS as part of the Hourly Surface, Hourly Precipitation and Daily Precipitation Composites.

US Bureau of Reclamation (USBR) AgriMet Network Data - The USBR operates this network of automated weather stations to assist irrigators in irrigation applications. Hourly observations of air temperature, relative humidity, dew point, wind speed and direction, solar radiation, precipitation and modified Penman evapotranspiration. There are 21 AgriMet stations within the LSA-NW (Figure 3-22). Data will be merged, quality controlled, and archived at the JOSS. These data will be made available from JOSS as part of the Hourly Surface, Hourly Precipitation and Daily Precipitation Composites.

USGS SAST Data - The USGS developed the Scientific Assessment and Strategy Team (SAST) to develop an environmental information system for the Upper Mississippi and Lower Missouri River basins in response to the 1993 floods in these basins. Data sets available include boundary data (i.e. state, county, USGS quadrangle, USGS hydrologic unit, etc), infrastructure data (i.e. roads, bridges, etc), hydrography data (i.e. lakes, rivers, reservoirs, etc), ecological data [i.e. land use, land cover, STATSGO (State Soil Geographic Database), forestry data, etc], hydrology and flood data (i.e. flood probability, levees, streamflow, etc), and raster data [i.e. Digital Elevation Model (DEM), Advanced Very High Resolution Radiometer (AVHRR), Landsat, SPOT, and European Remote Sensing (ERS)-1 flood images; not available on-line]. All data are in ARC/INFO Export format and/or Spatial Data Transfer Standard (SDTS) format. Sample GIF (Graphical Interchange Format) imagery is also available for some datasets. All data are available on-line via:

http://edcwww2.cr.usgs.gov/sast-home.html

USGS Mississippi Basin Carbon Project Data - The USGS is conducting the Mississippi Basin Carbon Project to examine interactions between the global carbon cycle and human-induced changes to the land-surface. There are five currently operational sites and seven other potential future sites. Within the LSA-NW there are five currently operational sites and four potential future sites (Figure 3-23). The data that is collected at these sites varies and we presently know of what is taken at lonly two sites, one of which is in the LSA-NW. The Trenyor, Iowa site has hourly measurements of soil water content (0-20 cm), soil water potential and soil temperature (10, 30, 60 and 90 cm at eroding hillslope and toeslope), sir temperature, solar radiation, wind speed, saturation vapor pressure, rainfall and pan evaporation (daily). Any data at this or any other present or future sites will be gathered by JOSS.

Wisconsin and Illinois Gravediggers Network Data - As a part of their wintertime duties, the Wisconsin and Illinois gravediggers report frost depth whenever a new "customer" arrives. Ancillary information such as slope, snow depth, tree cover and soil condition are also taken.

Colorado Agricultural Meteorological (CoAgMet) Network Data - The Colorado Climate Center routinely collects hourly observations of temperature, relative humidity, wind speed and direction, solar radiation, soil temperature (50, 100, and 150 mm depth), leaf wetness and precipitation. There are 31 CoAgMet sites in the LSA-NW (Figure 3-24). These data are collected from a variety of local agricultural networks and are archived by the Colorado Climate Center at Colorado State University. Data will be merged, quality controlled, and archived at the JOSS. These data will be made available from JOSS as part of the Hourly Surface, Hourly Precipitation and Daily Precipitation Composites.

Denver Urban Drainage and Flood Control District ALERT Data - The Denver Urban Drainage and Flood Control District operates an ALERT (Automated Local Evaluation in Real Time) network of over 50 precipitation stations, over 20 streamflow stations and 13 automated weather stations with 5-minute observations of air temperature, dew point and wind speed and direction. All of the stations are either in the Denver-Boulder metro area or in the adjacent mountain areas. Most of these data are included in other data sets to be collected by JOSS. Data will be merged, quality controlled, and archived at the JOSS. These data will be made available from JOSS as part of the Hourly Surface, Hourly Precipitation and Daily Precipitation Composites.

NOAA/ARL/Field Research Division (FRD) Southern Idaho Tower Network Data - NOAA/ARL/FRD operates a network of 34 instrumented towers in southeastern Idaho (Figure 3-25) with 5-min observations of air temperature (2 and 15 m), wind speed and direction, solar radiation and precipitation. The purpose of this network is for meteorological support and safety at the Idaho National Engineering and Environmental Laboratory. Data will be merged, quality controlled, and archived at the JOSS. These data will be made available from JOSS as part of the Hourly Surface, Hourly Precipitation and Daily Precipitation Composites.

USDA/ARS Reynolds Creek Experimental Watershed Data - The USDA/ARS started collection data at the Reynolds Creek Experimental Watershed in 1990. The watershed is in southwestern Idaho in a predominately rangeland watershed in the Owyhee Mountains. There are three automated weather stations on the watershed that provide hourly measurements of air temperature, relative humidity, wind speed and direction, solar radiation, soil temperature to depths of either 90 or 180 cm, precipitation, weighing lysimeters (at two sites) and pan evaporation. There are 16 sites with dual-precipitation gauges including a shielded gauge and an unshielded weighing gauge. Streamflow is measured at a number of locations on the watershed. Snow course measurements are taken at seven locations on a biweekly basis during the snow season. There is one snow pillow on site allowing for continuous snow water equivalent measurements. Soil moisture is measured at 14 sites on the watershed using gypsum resistance blocks at 5, 10, 15, 20 and 30 cm depths, at six of these sites frost tubes were included to provide measurements of frozen soils. Additionally over 100 wells and piezometers have been installed on the watershed to study ground water chemistry and hydrology. Data may be made available from JOSS.

Cook County Precipitation Network Data - This network of 25 precipitation gages is located on an 8 by 8 km grid over Cook County in northeast Illinois and is operated by USACE. These are weighing bucket data recorded

on strip charts. Hourly and daily accumulations are archived by the Illinois State Water Survey (ISWS). These sites are located just outside of the LSA-NW and there are some issues with the quality of these data. These data may be extracted and forwarded to JOSS. If they are received by JOSS these data will be merged, quality controlled, and archived at the JOSS. These data may be made available from JOSS as part of the Hourly Precipitation and Daily Precipitation Composites.

Illinois Climate Network (ICN) Data - The ISWS operates a network of 19 automated weather stations located throughout the state. Within the LSA-NW are three of the ICN stations (Figure 3-26). The data are sampled at 10 sec intervals with hourly averages archived. Each station collects measurements of barometric pressure, air temperature, relative humidity, wind speed, wind direction, solar radiation, and soil temperature at 5, 10, 20, 30, 40, 50, 60, 70, 80, 90, and 100 cm. These data will be extracted and forwarded to JOSS. Data will be merged, quality controlled, and archived at the JOSS. These data will be made available from JOSS as part of the Hourly Surface, Hourly Precipitation and Daily Precipitation Composites.

Illinois Department of Transportation (DOT) Network Data - The Illinois DOT, in conjunction with Surface Systems, Inc. (SSI), operates a network of 31 stations over the state of Illinois. The stations record precipitation, visibility, air temperature, wind speed, wind direction, road temperature, and road surface conditions data at hourly intervals. Given the lack of precipitation and difficulty in acquiring this data, it will probably not be collected by JOSS.

ISWS Soil Moisture Monitoring Network Data - The ISWS operates a network of 18 soil moisture monitoring sites throughout the state. Within the LSA-NW are four of the ISWS soil moisture monitoring sites (see Figure 3-26). Most of the sites are collocated with ICN sites. The measurements are conducted by a neutron depth probe and neutron surface moisture gage. The observations are collected once per month during the cold season and twice per month during the warm season. The sampling depth is 2 m. These data will be available from JOSS as a separate data set.

ISWS Shallow and Deep Ground-Water Observation Wells Data - The ISWS collects observations from 17 shallow and approximately 170 deep ground-water observation wells over the state.

Imperial Valley Water Authority Precipitation Network Data - This network of 25 precipitation gages is located on an 8 by 8 km grid in west-central Illinois and is operated by the Imperial Valley Water Authority. These are weighing bucket data recorded on strip charts. Hourly and daily accumulations are archived by ISWS. These sites are located within the LSA-NW, and there are some issues with the quality of these data. These data may be extracted and forwarded to JOSS. If they are received by JOSS these data will be merged, quality controlled, and archived at the JOSS. These data may be made available from JOSS as part of the Hourly Precipitation and Daily Precipitation Composites.

Davenport ALERT Network Data - The city of Davenport, Iowa in conjunction with the Davenport NWS office has set up an ALERT system with two river gauges and five rain gauges. Most of these data are included in other data sets to be collected by JOSS. Data will be merged, quality controlled, and archived at the JOSS. These data will be made available from JOSS as part of the Hourly Precipitation and Daily Precipitation Composites.

Iowa State University (ISU) Soil Moisture Survey Data - The ISU Extension Service conducts a twice yearly gravimetric survey of soil moisture across the state of Iowa. The measurements are typically conducted around early November and Early April. Measurements are taken at about 50 locations using core samples taken via a five foot tube. Measurements are taken at six inch intervals down to five feet. During the remainder of the year they model soil moisture through the use of the Shaw model (Shaw 1983). Both the observed and simulated soil moisture are archived at ISU. These data will be available from JOSS as a separate data set.

National Soil Tilth Laboratory (NSTL) Walnut Creek Watershed Energy Balance and Evapotranspiration Network Data - The NSTL has the capability to operate a network of 20 Bowen ratios energy balance stations in the Walnut Creek watershed located near Ames, Iowa. From the time of planting to harvest these provide estimates of latent and sensible heat fluxes via direct measurements of the net radiation; temperature, vapor pressure and wind speed at two levels; and soil heat flux. These fluxes are used to compute the

evapotranspiration of the field crops. The sampling frequency is 60 sec with average/total values every 30 min. During the time from harvest to planting (cold season) the stations provide net radiation, soil heat flux, and soil temperature similar to the warm season mode. However, the temperature, relative humidity and wind speed are collected from only a single level. The data sampling rates are the same. These stations are set up to examine specific research questions, thus the potential exists for the movement of these systems. The NSTL also operates two eddy correlation sites collocated with two of the Bowen ratio stations. Each site includes a sonic anemometer, thermocouple, and krypton hygrometer to directly measure the sensible and latent heat flux. Due to the sensitivity of the sonic to water, measurements are only made during periods with no possibility of precipitation. The data are 30 min averages and are archived by NSTL. JOSS will attempt to extract these data from NSTL and make them available as a separate data set.

NSTL Walnut Creek Watershed Meteorological Station Data - The NSTL operates two meteorological stations on the Walnut Creek watershed. One of the stations is on a lawn on a farmstead; the other is in a pasture. Each station measures hourly averages of air temperature, wind speed and direction, soil temperature (4, 10 and 20 cm depths), solar radiation, actual and saturated vapor pressure and rainfall. These data are archived by NSTL. These data will be extracted and forwarded to JOSS. Data will be merged, quality controlled, and archived at the JOSS. These data will be made available from JOSS as part of the Hourly Surface, Hourly Precipitation and Daily Precipitation Composites.

NSTL Walnut Creek Watershed Preipitation Network Data - The NSTL operates a network of 20 rain gauges in the Walnut Creek watershed. The stations are on an approximate one mile by one mile grid. All stations stations measure rainfall using tipping buckets and measure only warm season precipitation. The sites have hourly precipitation and air temperature. Both the hourly and daily data are archived at NSTL. The warm season data will be merged, quality controlled, and archived at the JOSS. These data will be made available from JOSS as part of the Hourly Precipitation and Daily Precipitation Composites.

NSTL Walnut Creek Watershed Surface and Groundwater Data - The USGS operates a network of five water quality monitoring and stream gauging stations in the Walnut Creek watershed. The network design allows for isolated study of surface water flow from three subwatersheds (13-20 $km^2$) and the entire watershed (47 $km^2$). Stage measurements are recorded every 5-min as are automatic stream temperature measurements. The NSTL also operates a network of three surface water runoff and water quality monitoring stations in the watershed. Stage values are measured every min with 5-min averages archived. Runoff samples are collected automatically during major runoff events.

Overland Park ALERT Network Data - The city of Overland Park, Kansas operates an ALERT network with four automated weather stations providing 15-min observations of air temperature, relative humidity, wind speed and direction, barometric pressure and precipitation. Also, there are 32 precipitation gauges and 10 streamflow gauges each providing 15-min values. Most of these data are included in other data sets to be collected by JOSS. Data will be merged, quality controlled, and archived at the JOSS. These data will be made available from JOSS as part of the Hourly Surface, Hourly Precipitation and Daily Precipitation Composites.

Minnesota Department of Natural Resources (DNR) Fire Weather Network (FWN) Data - The Minnesota DNR operates a network of 17 automated FTS weather stations (Figure 3-27). Twelve of the stations are funded by the Minnesota DNR, two by the USFS, two by the US Fish and Wildlife Service (USFWS) and one by the National Parks. The observations are hourly and represent an instantaneous value. The observed parameters include temperature, relative humidity, wind speed and direction and precipitation. These stations are not operational from November to early April. Data for the LSA-NW EAOP period will be extracted and forwarded to JOSS. The data will be merged, quality controlled, and archived at the JOSS. These data will be made available from JOSS as part of the Hourly Surface, Hourly Precipitation and Daily Precipitation Composites.

Minnesota DOT Network Data - The Minnesota DOT operates a network of 76 roadside weather stations throughout the state. For siting, they had input from meteorologists at the University of North Dakota. These stations are like most roadside networks in that they do not have precipitation measurements. Data for the LSA-

NW EAOP period may be extracted and forwarded to JOSS. The data may be merged, quality controlled, and archived at JOSS. These data may be made available from JOSS as part of the Hourly Surface Composite.

Minnesota Road Research Project (Mn/ROAD) Data - The Mn/ROAD project operates in Otsego, Minnesota about 40 miles northwest of Minneapolis. There are two automated weather stations on the site. First is the Vaisala Automated Weather Station located on the east end of the site. This station provides hourly measurements of air temperature, wind speed and direction, relative humidity, precipitation, barometric pressure and incoming and reflected solar radiation. Also operating at the site is a USACE Cold Regions Research and Engineering Laboratory (CRREL) weather station. This station is monitored by USACE and provides hourly measurements of air temperature, wind speed and direction, relative humidity, precipitation, barometric pressure, snow depth and incoming solar and long wave radiation. These data are archived by Mn/ROAD. JOSS will attempt to extract data for the LSA-NW EAOP period. If JOSS is able to acquire the data it will be merged, quality controlled, and archived at the JOSS. These data may be made available from JOSS as part of the Hourly Surface, Hourly Precipitation and Daily Precipitation Composites.

USGS Interdisciplinary Research Initiative (IRI) Site Data - The USGS operates the IRI site in the upper reach of the Shingobee River watershed in north central Minnesota. There are two primary lakes on the IRI site, Williams Lake is near the head of the Shingobee River watershed and is 5 km to the south-southeast of Shingobee Lake. The watershed of both lakes are generally forested. Data collected includes climatic data from rafts located on both lakes during the open water season as well as from a land-based station near Shingobee Lake. The stage of the lakes and discharge of the Shingobee River upstream and downstream from Shingobee Lake are monitored continuously. Water levels in about 70 groundwater wells are measured biweekly to monthly, however at select sites daily water level data are collected. There is also soil moisture monitoring at the site. JOSS will attempt to extract data for the LSA-NW EAOP period. If JOSS is able to acquire the data it will be merged, quality controlled, and archived at the JOSS. These data may be made available from JOSS as part of the Hourly Surface, Hourly Precipitation and Daily Precipitation Composites.

University of Minnesota (UM) Experiment Station Data - Dr. John Baker of the UM and the USDA/ARS collects a variety of data from several of the UM Experiment Stations. From the Experiment Station in ***Princeton, Minnesota*** (northwest of Minneapolis) data from one automated weather station are available. Hourly values of air temperature, relative humidity, wind speed, incoming and reflected solar radiation, incoming and outgoing longwave radiation, snow depth and precipitation from two sensors are collected. From the Experiment Station in ***Waseca, Minnesota*** (in south-central Minnesota) data from one automated weather station are available. Hourly values of air temperature, relative humidity, wind speed, incoming and reflected solar radiation, incoming and outgoing longwave radiation, snow depth and precipitation from one sensor are collected. From the Experiment Station in ***Rosemount, Minnesota*** (south of St. Paul) data from one automated weather station are available. Hourly values of air temperature, relative humidity, wind speed, incoming and reflected solar radiation and incoming and outgoing longwave radiation are collected. In addition, there are two precipitation sensors providing hourly precipitation, soil temperature and soil moisture sensors (5, 10, 16, 20, 31, 48, 65 and 100 cm depths), and a snow depth sensor. Also, there is one eddy covariance station that provides measurements of latent heat flux, virtual sensible heat flux, sensible heat flux and shear stress. Data for the LSA-NW EAOP period will be extracted and forwarded to JOSS. The data will be merged, quality controlled, and archived at the JOSS. These data will be made available from JOSS as part of the Hourly Surface, Hourly Precipitation and Daily Precipitation Composites as well as separate data sets.

UM Extension Climatology Network Data - The UM Extension Climatology operates a network of 16 station (Figure 3-28) which collect hourly average values of air temperature, precipitation, wind speed and direction, solar radiation, relative humidity and soil temperature at 10 and 20 cm depths. JOSS will attempt to extract data for the LSA-NW EAOP period. If JOSS is able to acquire the data it will be merged, quality controlled, and archived at the JOSS. These data may be made available from JOSS as part of the Hourly Surface, Hourly Precipitation and Daily Precipitation Composites.

Goodwater Creek Area Data - The Goodwater Creek watershed is located in north central Missouri. There are 15 (9) raingages operational during the warm (cold) season. There is one automated weather station on site (with both soil temperature and soil moisture measurements). There are also networks of glacial and alluvial aquifer

well nests and piezometers. JOSS may extract data for the LSA-NW EAOP period. The meteorological and precipitation data may be merged, quality controlled and archived at JOSS. These data may be made available from JOSS as part of the Hourly Surface, Hourly Precipitation and Daily Precipitation Composites.

Missouri Commercial Agriculture Weather Station (CAWS) Network Data - The University of Missouri Extension Service operates the CAWS network of 16 automated stations over the northern and southeastern sections of Missouri (Figure 3-29). They routinely archive hourly observations of temperature, relative humidity, bare soil temperature at 2 inches, wind speed, wind direction, incoming solar radiation, and precipitation. Data for the LSA-NW EAOP period will be extracted by the Department of Soil and Atmospheric Science at the University of Missouri and forwarded to the JOSS. The data will be merged, quality controlled, and archived at JOSS. These data will be made available from JOSS as part of the Hourly Surface, Hourly Precipitation and Daily Precipitation Composites.

Missouri Department of Conservation (DOC) FWN Data - The Missouri DOC operates a network of eight (they also collect data from three stations operated by the USFS and the US Park Service) automated FTS, Incorporated stations over the southern sections of Missouri (Figure 3-30). They archive hourly observations of temperature, relative humidity, wind speed, wind direction, and precipitation. Data for the LSA-NW EAOP period will be extracted and forwarded to JOSS. The data will be merged, quality controlled, and archived at JOSS. These data will be made available from JOSS as part of the Hourly Surface, Hourly Precipitation and Daily Precipitation Composites.

Novelty Watershed Experiment Field Data - The Novelty Watershed Experiment Field is comprised of three connected watersheds in north central Missouri. Each watershed has been instrumented with flumes, flow recorders and water samplers since 1991. There is also an automated weather station on site (which is included in the CAWS network).

Glacier National Park Field Station Data - Data sources from this location are still being looked into.

Montana DOT Network Data - The Montana DOT operates a network of 62 automated roadside weather stations over the state. Within the LSA-NW there are 59 stations (Figure 3-31). Hourly observations of air temperature, relative humidity and wind speed and direction are available. Like most roadside DOT networks, there is no precipitation data available. Data for the LSA-NW EAOP period may be extracted and forwarded to JOSS. The data may be merged, quality controlled, and archived at JOSS. These data may be made available from JOSS as part of the Hourly Surface Composite.

Northwest Montana ALERT Network Data - The Confederated Salish and Kootenai Tribe operates this ALERT network to support dam safety operations on their reservation in west central Montana. Observations of air temperature, relative humidity, wind speed and direction and precipitation are available (although it varies by station) from 20 stations over nrothwestern Montana (Figure 3-32). Data for the LSA-NW EAOP period may be extracted and forwarded to JOSS. The data may be merged, quality controlled, and archived at JOSS. These data may be made available from JOSS as part of the Hourly Surface, Hourly Precipitation and Daily Precipitation Composites.

Papio Basin ALERT Network Data - The Papio-Missouri River Natural Resources District operates (or used to operate) a network of 17 river gauges and two precipitation gauges in the area around Omaha, Nebraska. The system is only operational during the warm season from April to September. Most of these data are included in other data sets to be collected by JOSS. If the network still exists data may be merged, quality controlled, and archived at the JOSS. These data may be made available from JOSS as part of the Hourly Precipitation and Daily Precipitation Composites.

Sand Hills Region Data - Data sources from this location are still being looked into.

Grand Forks Air Force Base Network Data - The US Air Force (USAF) used to operate a network of 15 automated weather stations, it is not clear if the network still exists. These data were processed and archived at the University of North Dakota Regional Weather Information Center. If the network still exists data may be

merged, quality controlled, and archived at the JOSS. These data may be made available from JOSS as part of the Hourly Surface, Hourly Precipitation and Daily Precipitation Composites.

North Dakota Atmospheric Resources Board (NDARB) Cooperative Raingage Network Data - The NDARB oversees this network of over 840 volunteer observers (Figure 3-33). The NDARB exists to protect the rights of the public in cloud seeding operations. The network is only operational during the warm season and provides daily observations of precipitation amount. These data are archived by the NDARB. Data for the LSA-NW EAOP period may be extracted and forwarded to JOSS. The data may be merged, quality controlled, and archived at JOSS. These data may be made available from JOSS as part of the Daily Precipitation Composite.

Black Hills Hydrology Study Data - The USGS is conducting a 10-yr investigation of the surface and ground water of the Black Hills region of southwest South Dakota. There are approximately 39 precipitation stations (about a third of which are continuous and two-thirds human observer) of which about half are warm season only. Additionally there are about 70 observation wells on the site as well as a number (approximately 35) of streamgaging locations. All data are within the USGS data stream. Data for the LSA-NW EAOP period may be extracted and forwarded to JOSS. The data may be merged, quality controlled, and archived at JOSS. These data may be made available from JOSS as part of the Hourly Precipitation and Daily Precipitation Composites as well as in separate data sets.

Upper Missouri River Basin Pilot Project Data - During April and May of 1999 the South Dakota School of Mines and Technology in conjunction with other universities and organizations will be conducting this project to examine issues relating to precipitation variability, coupled atmospheric-land surface-subsurface processes, and scale area measurements of atmospheric moisture flux and its variability. There will be a set of enhanced observations available from this project.

Tooele Army Depot Network Data - The Deseret Chemical Depot of the US Army Chemical and Biological Defense Command and the county of Tooele, Utah operates this network of 36 stations near Tooele, Utah (near Salt Lake City; Figure 3-34). Each site provides 15-min observations of air temperature, relative humidity and wind speed and direction. Some sites also provide barometric pressure and precipitation. Data may be merged, quality controlled, and archived at the JOSS. These data may be made available from JOSS as part of the Hourly Surface, Hourly Precipitation and Daily Precipitation Composites.

US Army Dugway Proving Grounds Network Data - The US Army operates this network of 19 stations (Figure 3-35) at the Dugway Proving Grounds southwest of Salt Lake City. Each station provides 15-min observations of air temperature, relative humidity, wind speed and direction and barometric pressure. Data may be merged, quality controlled, and archived at the JOSS. These data may be made available from JOSS as part of the Hourly Surface, Hourly Precipitation and Daily Precipitation Composites.

Utah DOT Network Data - The Utah DOT operates this network of 13 roadside stations over the state (Figure 3-36). Each station provides 15-min observations of air temperature, relative humidity and wind speed and direction. There is no precipitation data available from these stations. Data for the LSA-NW EAOP period may be extracted and forwarded to JOSS. The data may be merged, quality controlled, and archived at JOSS. These data may be made available from JOSS as part of the Hourly Surface Composite.

USDA/NRCS Wisconsin Dense Till (WDT) Data - The NRCS operates the WDT Project which consists of 28 sites in northern and central Wisconsin. Soil moisture sensors (Fiberglass electrical resistance blocks) are at 12 depths (10, 25, 40, 50, 70, 85, 100, 120, 140, 160, 180, and 200 cm) at each site. Soil temperature is measured at three depths (25, 50, and 200 cm) at all sites except those in Taylor and Clark Counties which measures it at each of the 12 depths. The Forest, Vilas, and Lincoln County sites are in mixed forest vegetation. The Barron County sites includes both forested and cultivated conditions. Some of the locations in Clark and Taylor Counties are cultivated. Some of the non-forested locations include both fields and adjacent non-cultivated field edges for comparison.

Measurements are made bi-weekly during the summer and monthly during the winter. Dataloggers were installed at the Clark, Taylor, and Forest County locations allowing hourly readings to be made. Data are archived at the

NRCS National Soil Survey Center (NSSC) in Lincoln, Nebraska. If this effort is still underway, JOSS will attempt to collect the data and make it available as a separate data set.

University of Wisconsin (UW) Agricultural Weather Observation Network (AWON) Data - The UW Soils Science Department operates a network of 18 stations throughout the state at UW Experiment Stations (four of which are in the LSA-NW; Figure 3-37). The stations provide measurements of air temperature, relative humidity, wind speed, wind direction, solar radiation, and soil temperature at 2, 4, 20, and 40 in. Not all stations measure the relative humidity and some also do not measure the soil temperature at all levels. These data are hourly average values. Hourly total precipitation and peak 5 sec and 1 min wind gusts are also recorded. Two stations (Cranmoor and Manitowish Waters) are located over cranberry bogs for low temperature forecast verification. These two sites have a 10 m tower set up with the following measurements: 1.5 m temperature and relative humidity, 2 m pyranometer, 3 m wind speed and direction, and 10 m temperature, relative humidity, and wind speed and direction. They also have a tipping bucket gage for precipitation. These data are archived by the UW Soils Science Department and data for the LSA-NW EAOP will be extracted by JOSS. The data may be merged, quality controlled, and archived at JOSS. These data may be made available from JOSS as part of the Hourly Surface, Hourly Precipitation and Daily Precipitation Composites as well as in separate data sets.

Wisconsin DNR FWN Data - The Wisconsin DNR operates this network of 19 automated FTS weather stations (Figure 3-38). The stations are a joint effort of the Wisconsin DNR, USFS and the USFWS. The observations are hourly and represent an instantaneous value. The observed parameters include temperature, relative humidity, wind speed and direction and precipitation. These stations are not operational from November to early April. Data for the LSA-NW EAOP period will be extracted and forwarded to JOSS. The data will be merged, quality controlled, and archived at the JOSS. These data will be made available from JOSS as part of the Hourly Surface, Hourly Precipitation and Daily Precipitation Composites.

Wisconsin DOT Network Data - The Wisconsin DOT, in conjunction with SSI, operates a network of 51 roadside pavement sensors throughout the state of which 25 are in the LSA-NW (Figure 3-39). The parameters observed include temperature, dew point, relative humidity, wind speed, wind direction, and yes/no precipitation. These data are hourly instantaneous values. Four sites have optical weather indicators that provide estimated precipitation rate and accumulation. They are typically about 10-30 feet from roadways and are over mowed grassland. There is no precipitation data available from these stations. Data for the LSA-NW EAOP period may be extracted and forwarded to JOSS. The data may be merged, quality controlled, and archived at JOSS. These data may be made available from JOSS as part of the Hourly Surface Composite.

Greater Yellowstone Experiment Data - Data sources from this location are still being looked into.

Wyoming DOT Network Data - The Wyoming DOT operates this network of 21 stations over the state (Figure 3-40). Each station provides 15-min observations of air temperature, relative humidity and wind speed and direction. There is no precipitation data available from these stations. Data for the LSA-NW EAOP period may be extracted and forwarded to JOSS. The data may be merged, quality controlled, and archived at JOSS. These data may be made available from JOSS as part of the Hourly Surface Composite.

LSA-NW EAOP Hourly Surface Composite - This composite will contain surface and sea level pressure, temperature, dew point, wind speed and direction, and precipitation hourly observations from surface observing sites in the LSA-NW 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 will not contain the precipitation data from those sites that collect only precipitation data (i.e. the site must also collect meteorological observations to be included). The precipitation only sites will be contained within the precipitation composites which are described below. The composite will be produced by the JOSS and contain hourly data from the following networks: ASOS, AWOS, SAO's and others (see Figure 4-1). These data will be quality controlled by JOSS (see section 4.1.1).

LSA-NW EAOP Hourly Precipitation Composite - The hourly precipitation composite will contain precipitation data from all real-time and recording gages in the LSA-NW. The composite will be produced by the JOSS and

contain hourly totals from gages in the following networks: ASOS, AWOS, SAO's, CAWS, NWS Cooperative Observer and others (see Figure 4-2). These data will be quality controlled by JOSS (see section 4.1.2).

LSA-NW EAOP Daily Precipitation Composite - The daily precipitation composite will contain precipitation data from all real-time and recording gages in the LSA-NW. The composite will be produced by the JOSS and contain daily totals from gages in the following networks: ASOS, AWOS, SAO's, CAWS, NWS Cooperative Observer, USGS, USACE and others. These data will be quality controlled by JOSS (see section 4.1.2).

### 3.1.2 Upper Air Data

DOE ARM SGP CART Microwave Radiometer (MWR) Data - The DOE ARM program operates a network of MWR systems at its SGP site that provide measurements of microwave radiation from the sky at 23.8 and 31.4 Ghz which allow for the determination of atmospheric water vapor and liquid water. MWR systems are operational at the four ARM boundary facilities as well as the ARM central facility. Three of the MWR systems are within the LSA-NW (Figure 3-41). The data are collected and processed by the DOE ARM Program and are archived at DOE ORNL.

DOE ARM SGP CART Sounding Network Data - The DOE ARM program operates a network of five radiosonde locations at the four ARM SGP boundary facilities as well as the ARM SGP central facility (see Figure 3-41). Observations of air temperature, relative humidity, wind speed and direction, and altitude are collected at 2-sec vertical intervals. The routine observations are four soundings per weekday (0000, 0600, 1200 and 2030 UTC) at only the central facility. There are no routine releases at the boundary facilities. During some Intensive Observing Periods (IOPs) soundings are taken at all five sites at up to three hour intervals. The data will be collected and processed by the DOE ARM program and archived at the DOE ORNL. Data for the LSA-NW EAOP will be extracted and forwarded to JOSS. All data will be converted to a common ASCII sounding format and quality controlled (see Section 4.1.4).

DOE ARM SGP CART AERI Data - The University of Wisconsin is operating five Atmospherically Emitted Radiance Interferometer (AERI) systems at the four ARM SGP boundary facilities as well as the ARM SGP central facility (see Figure 3-41). AERI is a ground-based high resolution interferometer which provides measurements of infrared radiation yielding radiance spectra which are then transformed to vertical temperature and water vapor profiles in the planetary boundary layer. The profiles are generated every 10 minutes. The data are collected and processed by the DOE ARM program and archived at the DOE ORNL.

DOE ARM SGP CART Boundary Layer Profiler Data - The DOE ARM program operates a network of three 915 MHz wind profilers at the ARM SGP intermediate facilities. Each site also has a Radio Acoustic Sounding System (RASS) as well. The profilers measure wind profiles from 0.1 to 5 km and the RASS measure virtural temperature profiles from 0.1 to 1.5 km. The data are collected and processed by the DOE ARM program and archived at the DOE ORNL.

DOE ARM SGP CART 60-m Tower Data - The DOE ARM program operates a 60 m tower at the ARM SGP central facility. Measurements of air temperature and relative humidity are available at the 25 and 60 m levels on the tower and at both 1-min and 30-min intervals. The data are collected and processed by the DOE ARM program and archived at the DOE ORNL.

DOE ARM SGP CART Vaisala Ceilometer Data - The DOE ARM program operates a network of four Vaisala Ceilometers at the ARM SGP boundary facilities. The Vaisala Ceilometers are a ground-based active remote sensing device designed to measure cloud base height at up to three levels and potentially backscatter signals by aerosols. The data are collected and processed by the DOE ARM program and archived at the DOE ORNL.

NWS Upper Air Rawinsonde Data (6-sec vertical levels) - These data will contain 12-hourly (occasionally more frequent at the request of the NWS) vertical profiles of time, pressure, temperature, altitude, relative humidity, wind speed and direction, 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 will be obtained from 17 NWS sites in the LSA-NW

(Figure 3-42). All data will be processed by the JOSS. Data are collected and archived by NCDC. Data for the LSA-NW EAOP will be extracted and forwarded to JOSS. All data will be converted to a common ASCII sounding format and quality controlled (see Section 4.1.4).

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 are routinely collected at 72 sites over all of the conterminous US and archived at NOAA/NCDC. Data for the LSA-NW (see Figure 3-42) will be archived and available at NCDC. Also, these data are available for a period of time from NOAA/FSL, and JOSS will extract those for the LSA-NW EAOP period and make them available. These will not be converted nor quality controlled by JOSS.

Canadian Upper Air Rawinsonde Data (10-sec vertical levels) - These data will contain 12-hourly vertical profiles of time, pressure, temperature, altitude, relative humidity, wind speed and direction, complete with quality flags, at 10-sec intervals. If available, these high resolution data will possibly be obtained from four stations in the LSA-NW (see Figure 3-42).

Canadian 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 are routinely collected at sites throughout Canada and archived at NOAA/NCDC. Data for the LSA-NW (see Figure 3-42) will be archived and available at NCDC. Also, these data are available for a period of time from NOAA/FSL, and JOSS will extract those for the LSA-NW EAOP period and make them available. These will not be converted nor quality controlled by JOSS.

NOAA Profiler Network (NPN) Data - The NPN routinely collects vertical profiles of hourly component winds (u, v, and w) and six-minute radar return spectral moments, both with 250 meter resolution. These data are available from 20 405 MHz profiler sites within the LSA-NW (see Figure 3-7). Three sites within the LSA-NW have collocated RASS. The data are routinely collected and processed by NOAA/FSL and archived at NOAA/NCDC. Data for the LSA-NW period will be extracted and forwarded to the JOSS.

Boundary Layer Profiler Data - There are 12 boundary layer (915 MHz) profilers within the LSA-NW. However NOAA/FSL presently does not routinely receive data from any of these sites. If NOAA/FSL acquires the data from any of these profilers and processes it into hourly, quality controlled products, and archives the data, JOSS will attempt to extract the data for the LSA-NW period.

### 3.1.3 Radar Data

WSR-88D Data - There are 35 Weather Service Radar - 1988 Doppler (WSR-88D) radars within the LSA-NW (Figure 3-43). Data from the WSR-88D network 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 browse 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 are routinely archived and available at the NOAA/NCDC.

WSR-88D NIDS Data - The NEXRAD (now WSR-88D) Information Dissemination Service (NIDS) will be provided to JOSS from 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). A preliminary group of four radars have been selected for

NIDS data collection during the LSA-NW EAOP period (Figure 3-43). JOSS will extract and archive as many of those radars of interest to the LSA-NW EOP as is possible.These data will be archived at JOSS.

WSI Reflectivity Composite Imagery - The WSI routinely produces and distributes a mosaic of reflectivity from all NWS radars in the conterminous US. The product, called NOWRAD, is available at a variety of resolutions and coverages in real time. For LSA-NW EAOP, 2 km data will be recorded at 15 minute intervals in a fixed sector overlaying the LSA-NW. From this data set a representative daily image will be selected at 12 UTC, or the closest available time, to coincide with the NOAA/National Centers for Environmental Prediction (NCEP) Eta model daily weather map imagery and the Geostationary Operational Environmental Satellite (GOES)-8 infrared image. The selected daily images will be translated to GIF. These will be available online for browsing purposes. The full 15-min dataset in its original format will be available directly from JOSS. These images will be obtained by the JOSS from the NIDS data stream (US contiguous composite).

NASA/MSFC National Reflectivity Composite - The NASA/Marshall Space Flight Center (MSFC) ingests 15-min 2 km NOWRAD composite data for the conterminous US. The 2 km data are available in HDF (Hierarchical Data Format) only. These files will be translated to 8 km GIF and provided to JOSS. JOSS will select representative daily imagery at 1200 UTC (or the closest available time) and they will be available for online browse purposes. A daily continental US composite precipitation summary is also being derived from the composite radar data. These daily rainfall data are also available in 2 km HDF or 8 km GIF format from NASA/MSFC/Global Hydrology Resource Center (GHRC).

NCEP National Precipitation Analysis (NPA) Data - NCEP in cooperation with NOAA/OH has developed a real-time, hourly, multi-sensor NPA. The NPA is a merger of two data sources. The hourly digital precipitation radar estimates from the WSR-88D Radar Product Generator on a 4 km grid centered over each radar site. A bias correction of the radar estimates using raingages on a 4 km grid over the US. The following data sets are forwarded to JOSS (all in 4 km GRIB [Grid point values expressed in Binary format]): multi-sensor analysis (gage and unbiased radar), gage-only analysis, radar estimate and radar estimate after bias removal.

NOAA/RFC Stage III WSR-88D Data - The NOAA/RFCs routinely produce an hourly composite derived precipitation product from all the WSR-88D radars covering their region of responsibility. These data are on a 4 km by 4 km grid and are in GRIB. These data are 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. Data for the LSA-NW EAOP period will be extracted and forwarded to JOSS. The JOSS will provide daily 24-hr total precipitation estimate GIF imagery for online browse purposes. Measurement of solid precipitation is difficult with radar. Algorithms to improve this product are currently under development. The NEXRAD Precipitation Processing System Stage III data which encompasses snow will be flagged and should be used with caution as to the quantitative precipitation values provided.

**Table 3-2 WSR-88D NIDS Products and Descriptions**

***Reflectivity***

The first four tilt angles are available. The resolution is 1 km by $1^{o}$.

***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 $1^{o}$.

***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**: Parameters underlined and italicized are collected and available from JOSS.

## 3.1.4 Land Characterization Data

PSU 1-km Multi-Layer Soil Characterization Data Set - The Pennsylvania State University (PSU) has developed a 1-km Multi-Layer Soil Characterization Data Set based on the USDA 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), depth-to-bedrock coverage, bulk density coverages, hydrologic soil group coverage, available water capacity, 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). Data are also available in any of three projections, Lambert Azimuthal, Albers Equal Area, and geographic coordinates (latitude/longitude). Data are processed and archived at the PSU Earth System Science Center.

Earth Resources Observing Systems (EROS) Data Center (EDC) Bi-Weekly Vegetation Index Data - Satellite-derived values of vegetation index are routinely produced at NOAA/National Environmental Satellite, Data and Information Service (NESDIS) and EDC. The land cover imagery is produced bi-weekly from 1 km resolution

AVHRR and translated to GIF by EDC. The full database is available on CD-ROM from EDC. GIF imargery for the LSA-NW EAOP period may be forwarded to JOSS by EDC.

EDC Global Land 1-km AVHRR Data - EDC compiled this data from 5-channel, 10 bit, raw AVHRR data at 1.1 km resolution (at nadir) for every daily afternoon pass over all land and coastal zones using NOAA's polar orbiting Television and Infrared Observation Satellite (TIROS). The data were collected for the period 1 April 1992 to 30 September 1996. These data are available from EDC.

EDC Global 30 Arc Second Elevation Data - EDC compiled this DEM with a horizontal grid spacing of 30 arc seconds (approximately 1 km) from several raster and vector sources of topographic information. These data are available from EDC.

EDC Hydro 1-k Elevation Derivative Data - EDC developed this data set from the Global 30 Arc Second Elevation data set. Data includes hydrologically correct DEM, slope, aspect, flow directions, flow accumulation, and the Compound Topographic (Wetness) Index. These data are available from EDC.

## 3.2 Satellite Data

Remotely sensed information and products will play a vital role in the accomplishment of the science objectives in the LSA-NW. General information on the availability can be obtained from the Satellite Remote Sensing Data Source Module at NASA/MSFC (see Section 5). This includes the availability and archival location of data and products from NOAA, NASA, the Department of Defense (DOD) and commercial satellites and instruments as well as international satellites.

### 3.2.1 Operational Satellite Data

Two changes this year to the existing satellite and instruments are the GOES 10 and NOAA 15. GOES 10 replaced GOES 9 so the products stream continues. In addition to the normal compliment of instruments, NOAA 15 has the Advanced Microwave Sounding Unit (AMSU A and B). This instrument has some frequencies similar to those of the Defense Meteorological Satellite Program (DMSP) Special Sensor Microwave/Imager (SSM/I) as well as increased spectral resolution for more detailed atmospheric temperatures. Products are being generated from this instrument.

Generally, instrument data and some products are archived at the national centers. These include vegetation index, TOVS (Television and Infrared Observation Satellite [TIROS] Operational Vertical Sounder) soundings, monthly heat budget products, SSM/I derived geophysical products, and GOES vertical temperature profiles, layer precipitable water, total precipitable water and GOES visible (VIS), Infrared (IR), and water vapor (WV) data. Further details on these data products are available through the Satellite Remote Sensing Data Source Module (see Section 5). Table 3-3 (all acronyms within Tables 3-3 to 3-6 are defined in Appendix A) gives a listing of the pertinent data products available from the current operational satellites.

**Table 3-3 Existing Satellite Products**

| SATELLITE DATA | CENTER |
|---|---|
| POES Radiation Budget Data (4/day)<br>Outgoing longwave (AVHRR) and<br>Planetary albedo (AVHRR) | NESDIS |
| GCIP Surface Radiation Budget<br>Surface downward flux<br>Surface downward PAR<br>TOA downward flux<br>TOA upward flux | NESDIS & University of Maryland |
| POES/AVHRR Vegetation Index (weekly/monthly) | NCDC |

| | |
|---|---|
| DMSP SSM/I Snowcover (daily) | NOHRSC |
| POES CLAVR Clouds (2/day) | NCDC |
| GOES/ASOS Clouds (hourly) | NESDIS |
| GOES Continental US Sector Imagery (IR, VIS and WV) | UCAR/JOSS & GHCC |
| Gridded Areal Snow Cover (daily/weekly) | NOHRSC |
| Gridded Snow Water Equivalent (weekly) | NOHRSC |

NOAA Airborne Gamma Snow Survey Data - The NOAA/National Operational Hydrologic Remote Sensing Center (NOHRSC) operates the Airborne Gamma Snow Survey Program. Radiation detection systems on-board low-flying aircraft are used to measure the gamma radiation emitted from trace elements of potassium, uranium, and thorium radioisotopes in the upper 20 cm of the soil. The water mass in the snow attenuates the terrestrial radiation signal. Thus, the difference between the radiation measurements over bare ground and snow-covered ground is used to derive a mean areal snow water equivalent (SWE). Soil moisture surveys are often conducted in the late fall so that an accurate soil moisture value is available to derive the SWE during the winter. The typical survey operations are conducted from January through April using two aircraft simultaneously. Each flight line is typically 16 km long and 300 m wide, or an area of approximately 5 $km^2$. As such, each SWE measurement is a mean areal measure integrated over the 5 $km^2$ area of the flight line. These SWE and upper 20 cm soil moisture data are available in GIF, GRASS, ARC/INFO, and ASCII text formats with a resolution of 30 arc seconds and at a variable frequency. Also available are the SWE and soil moisture line and sub-line data for research use.

### 3.2.2 Future Satellite Data

In addition to the established suite of operational satellites and instruments, three new satellite systems are planned to be operational starting in 1999. These are NASAs Terra (formerly Earth Observing System [EOS] AM-1), LANDSAT 7 and Space Imaging's IKONOS. Information about the satellite and instruments is available in Table 3-4. These satellites have more sensitive instruments, better calibration procedures, peer reviewed algorithms to generate products, and higher spatial resolutions on some instruments. With expected launch dates in the first half of 1999, data and products should be available around the start of water year 2000.

Terra will overfly the LSA-NW area around 10:30 local in the morning and 10:30 at night. Some of its products will be available for both periods, while others will be available only during the day. LANDSAT 7 will provide information around 10:00 AM, while IKONOS is expected to provide data around 10:30 AM. Of particular significance are the bands in the visible portion of the spectrum. The spatial resolution of the Moderate Resolution Imaging Spectrometer (MODIS) bands used for land properties is 500 m, while LANDSAT 7 will be 30 m, and IKONOS will be 4 m.

The particular ground trace of the satellite and the coverage will change from day to day, but with a ground coverage of 2300 km perpendicular to the satellite flight path, data and products for the LSA-NW will be contained in at most two consecutive orbits.

NASA will produce ober 60 high quality products, pertinent to GCIP research, from the instruments on Terra. The Level 1 sensor data products are listed in Table 3-5. These data products consist of either the raw sensor data or the reprocessed sensor data with calibration and Earth location information attached but not applied to the data. A complete listing of the Level 1 and Level 2 sensor data products is shown in Table 3-6. The Product ID is a reference number that is important when the products are ordered from the appropriate NASA Distributed Active Archive Center (DAAC). More detailed information about the individual products is available online at

http://eospso.gsfc.nasa.gov/eospso_homepage.html

Each product is described in detail. Earth Resources Observation Systems (EROS) Data Center (EDC) will process all LANDSAT 7 data received to "Level 0R" (i.e. corrected for scan direction and band alignment but

without radiometric or geometric correction) and archive the data in that format. A systematically corrected product (Level 1G) will be generated and distributed to users on request. Space Imaging, Inc. products from IKONOS are orthorectified satellite images, which removes the horizontal errors that result from terrain variations.

| Table 3-4 GCIP Satellite Information (1999-2000) | | | | | |
|---|---|---|---|---|---|
| Future Satellites | Sensors | Bands | Waveband | Spatial Resolution | Swath Width |
| Terra | ASTER | 3 | 0.5-0.9μm, 1.6-2.43μm & 8-12μm | 15m (VNIR)<br>30m (SWIR)<br>90m (TIR) | 106km (SWIR &TIR)<br>304km(VNIR) |
| | CERES | 3 | 0.3->50μm, 0.3-0.5μm & 8-12μm | 21km (nadir) | Limb to Limb |
| | MISR | 4 | 443nm, 555nm, 670nm & 865nm | 275m, 550m, 1.1km | 360km |
| | MODIS | 36 | 21 bands (0.4-3.0μm)<br>15 bands (3.0-14.5μm) | 250m, 500m, 1km | 2330km |
| | MOPIT | 3 | 2.3, 2.4, 4.7μm | 22km | 616km |
| IKONOS 1 | PS | 1 | 0.45-0.9μm | 1m | 11km |
| | MSS | 4 | 0.45-0.88μm | 4m | 11km |
| LANDSAT 7 | ETM+ | 8 | 0.45-2.35μm | 30m, 15m | 185km |

| Table 3-5 Terra Level 1 Sensor Data Products (ungridded) | | |
|---|---|---|
| **Product** | **Title** | **DAAC** |
| | **ASTER** | |
| AST01 | ASTER Reconstructed, Unprocessed Instrument data | EDC |
| AST03 | ASTER Registered Radiance at Sensor | EDC |
| | **MISR** | |
| MIS01 | MISR Reformatted Annotated Product | LaRC |
| MIS02 | MISR Radiometric Product | LaRC |
| MIS03 | MISR Geo-rectified Radiance Product | LaRC |
| | **CERES** | |
| CER/BDS | Bi-Directional Scan Products | LaRC |
| | **MODIS** | |
| MOD01 | Level-1A Radiance Counts | GSFC |
| MOD02 | Level-1B Calibrated, Geolocated Radiances | GSFC |
| MOD03 | Geolocation Data Set | GSFC |

| Table 3-6 Terra Satellite Data Products | | |
|---|---|---|
| **Product** | **Title** | **DAAC** |
| | | |

| | | |
|---|---|---|
| | **ASTER** | |
| AST01 | ASTER Reconstructed, Unprocessed Instrument Data | EDC |
| AST03 | ASTER Registered Radiance at Sensor | EDC |
| AST04 | ASTER Brightness Temperature at Sensor | EDC |
| AST05 | ASTER Surface Emissivity | EDC |
| AST06 | ASTER Decorrelation Stretch | EDC |
| AST07 | ASTER Surface Reflectance | EDC |
| AST08 | ASTER Surface Kinetic Temperature | EDC |
| AST09 | ASTER Surface Radiance | EDC |
| AST13 | ASTER Polar Surface and Cloud Classification | EDC |
| AST14 | ASTER Digital Elevation Models (DEMs) | EDC |
| | **MISR** | |
| MIS01 | MISR Reformatted Annotated Product | LaRC |
| MIS02 | MISR Radiometric Product | LaRC |
| MIS03 | MISR Geo-rectified Radiance Product | LaRC |
| MIS04 | MISR TOA and Cloud Product | LaRC |
| MIS05 | MISR Aerosol and Surface Product | LaRC |
| MIS06 | MISR Global Radiation Product | LaRC |
| MIS07 | MISR Global Could Product | LaRC |
| MIS08 | MISR Global Aerosol Product | LaRC |
| MIS09 | MISR Global Surface Product | LaRC |
| MIS10 | MISR Ancillary Geographic Product | LaRC |
| MIS11 | MISR Ancillary Radiometric Product | LaRC |
| MIS12 | MISR Aerosol Climatology Product | LaRC |
| | **CERES** | |
| CER/BDS | Bi-Directional Scan Products | LaRC |
| CER/ES-8 | ERBE-Like Product, Unfiltered Radiances, TOA Fluxes | LaRC |
| CER/ES-9 | Earth Radiation & Atmospheric Data ERBE-Like Product | LaRC |
| CER/ES-4 | Gridded Fluxes-ERBE-Like Product | LaRC |
| CER/ES4-G | Gridded Fluxes-ERBE-Like Product | LaRC |
| CER/SSF | Single Satellite Footprint TOA and Surface Fluxes and Clouds | LaRC |
| CER/CRS | Single Satellite CERES Footprint Radiative Fluxes and Clouds | LaRC |
| CER/FSW | Hourly Gridded Single Satellite Fluxes and Clouds | LaRC |
| CER/SYN | Synoptic Radiative Fluxes and Clouds | LaRC |
| CER/AVG | Regional Average Data Product | LaRC |
| CER/ZAVG | Zonal and Global Monthly Average Data Product | LaRC |
| CER/SFC | Gridded Single Satellite Fluxes and Clouds | LaRC |
| CER/SRBAVG | Monthly TOA and Surface Radiation Budget Averages | LaRC |
| | **MODIS** | |
| MOD01 | Level-1A Radiance Counts | GSFC |
| MOD02 | Level-1B Calibrated, Geolocated Radiances | GSFC |

| | | |
|---|---|---|
| MOD03 | Geolocation Data Set | GSFC |
| MOD04 | Aerosol Product | GSFC |
| MOD05 | Total Precipitable Water | GSFC |
| MOD06 | Cloud Product | GSFC |
| MOD07 | Atmospheric Profiles | GSFC |
| MOD08 | Gridded Atmospheric Product | GSFC |
| MOD09 | Surface Reflectance; Atmospheric Correction Algorithm Products | GSFC |
| MOD10 | Snow Cover | NSIDC |
| MOD11 | Land Surface Temperature and Emissivity | EDC |
| MOD12 | Land Cover/Land Cover Change | EDC |
| MOD13 | Vegetation Indices | EDC |
| MOD14 | Thermal Anomalies - Fires and Biomass | EDC |
| MOD15 | Leaf Area Index and Fractional Photosynthetically Active Radiation | EDC |
| MOD16 | Evapotranspiration | EDC |
| MOD17 | Vegetation Production, Net Primary Productivity | EDC |
| MOD18 | Normalized Water-leaving Radiance | GSFC |
| MOD22 | Photosynthetically Available Radiation | GSFC |
| MOD32 | Processing Framework and Match-up Database | GSFC |
| MOD33 | Snow Cover | NSIDC |
| MOD34 | Gridded Vegetation Indices (Max NDVI and Integrated MVI) | GSFC |
| MOD35 | Cloud Mask | GSFC |
| MOD36 | Total Absorption Coefficient | GSFC |
| MOD40 | Gridded Thermal Anomalies | EDC |
| MOD43 | Surface Reflectance, BRDF/Albedo Parameter | EDC |
| MOD44 | Vegetation Cover Conversion | EDC |

## 3.3 Model Output

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

The emphasis for model output during GCIP has been and continues to be on the regional mesoscale models with output from the following three models:

(i) Atmospheric Environment Service/Canadian Meteorological Centre (AES/CMC) Global Environmental Multiscale
(GEM) Model (formerly the Regional Finite Element [RFE] Model)
(ii) NOAA/NCEP Eta 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 surface 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 Datasets (MORDS).
(3) Gridded three-dimensional atmospheric fields containing all of the atmospheric variables produced by the models.

The archived model output has provided coverage over the LSA-NW from the beginning of the archive period and will continue during the data collection period for the LSA-NW EAOP.

The focus of GCIP is on the regional numerical weather prediction (NWP) model output as noted above. However, there are other model output data which provide coverage over the Mississippi which GCIP investigators can request from the appropriate archive center. A listing of the model output data for the full CSA is provided in Table 3-7.

AES/CMC GEM Model Output - The AES/CMC archives operational output from the GEM model including output from its data assimilation system. The GEM operates in analysis (6-hr intervals) and forecast (12-hr intervals) cycles with forecasts up to 24 hours. Table 3-8 provides characteristics of the model. The vertical levels are at a variable spacing, with higher resolution in the lower levels. Model output will be archived by the AES/CMC.

NOAA/FSL MAPS Model Output - The NOAA/FSL will run the MAPS model every 3 hours with up to 12 hour forecasts during the LSA-NW EAOP. Characteristics of the model are provided in Table 3-8. The data cutoff for model runs is approximately 1 hour, and the output format is GRIB. These output data will be archived by NOAA/FSL.

NOAA/NCEP Eta Model Output -The NOAA/NCEP will provide operational output from its regional Eta model including output from the Eta Data Assimilation System (EDAS). The Eta operates in analysis and forecast cycles at 6-hr intervals with forecasts provided up to 24 hours. The EDAS is also run at the intermediate 3-hourly intervals to produce eight analyses per day. Table 3-8 provides characteristics of the model. The horizontal resolution for GCIP is constant regardless of the resolution of the model. These data will be archived by NCAR/SCD.

NOAA/NCEP Eta Model 12 UTC Initial Analysis GIF Imagery - JOSS receives NOAA/NCEP Eta model initial analyses and converts them to GIF imagery for browse purposes. 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.

**Table 3-7 Model Output Data for CSA During the LSA-NW EAOP**

| DATA DESCRIPTION | DATA AVAILABILITY | |
|---|---|---|
| Eta Data Assimilation System (EDAS) (3-hrly) | X | |
| Eta Model Forecast (12-hrly) | X | |
| Eta Model Initialization Analysis GIF Imagery (daily; 12 UTC) | | UCAR/JOSS |
| Eta MOLTS (hrly) and MORDS (3-hrly) | X | |
| Eta Model MOLTS Derived Initial Sounding Output (12-hrly) | | UCAR/JOSS |
| Eta Fixed Fields (including land surface) | X | |
| GEM Model Analyses (8-hrly) (MORDS) | X | |
| GEM Model Forecasts (12-hrly) (MORDS) | X | |
| GEM MOLTS (hrly) | X | |
| | | |

| | | |
|---|---|---|
| GEM MOLTS Derived Initial Sounding Output (12-hrly) | | UCAR/JOSS |
| GEM 3-D Fields | | AES/CMC |
| GEM Fixed Fields | X | |
| MAPS Model Output 3-D Fields | | NOAA/FSL |
| MAPS Model Output (MOLTS and MORDS) | X | |
| **Atmospheric Global Models** | | |
| NCEP Medium Range Forecasts (MRF) (12-hrly) | | NCAR/DSS |
| CMC Global Spectral Model (12-hrly) | | AES/CMC |
| ECMWF Medium Range Weather Forecast Model (Daily) | | ECMWF |
| NCEP Climate Data Assimilation System (CDAS) (Daily) | | NCAR/DSS |
| **Hydrology Models** | | |
| RFC Hydrology Model Data (8-hrly) | TBD | TBD |
| **Derived Data Products** | | |
| National Precipitation Analysis (Daily) | X | NCAR/DSS |

**Table 3-8 Regional Model Characteristics**

| Model | Analysis Cycles (h) | Forecast Cycles (h) | Forecast Length (h) | Resolution (km) | Vertical Levels | MOLTS in LSA-NW | MOLTS parameters Upper Air/ Surface |
|---|---|---|---|---|---|---|---|
| Eta | 3 | 6 | 48 | 40 | 38 | 101 | 13/56 |
| GEM | 6 | 12 | 24 | 24 | 28 | 97 | 31/17 |
| MAPS | 3 | 3 | 6 | 40 | 40 | 101 | 16/27 |

MOLTS Output - The NOAA/NCEP Eta, NOAA/FSL MAPS, and AES/CMC GEM models will be providing vertical and surface hourly time series of model output at selected locations (MOLTS). The fundamental output variables for the MOLTS are shown in Table 3-9. The MOLTS list from a specific model may add other parameters depending on the choice of physics package or other non-GCIP user requirements. Some examples for the surface parameters could include turbulent kinetic energy and other diabatic heating and moistening rates, such as those due to vertical and horizontal diffusion. Some examples of the non-profile variables could include canopy water content, boundary layer depth, convective storm stability indices, precipitation type, etc. All of these output will be archived in BUFR (Binary Universal Form for data Representation) format at NCAR/SCD.

The NOAA/NCEP Eta model MOLTS output will be available from 311 locations over North America. Within the LSA-NW there will be 101 locations (Figure 3-44). These output will contain 40 surface state and flux parameters and 12 parameters at each of the 38 vertical levels. Output will be provided from the 00 and 12 UTC runs from the initial analysis time out to 48 hours.

The AES/CMC GEM model MOLTS output will be available from 252 locations over North America. Within the LSA-E there will be 97 locations (Figure 3-44). These output will contain 17 surface parameters and 31 parameters at each of the 28 vertical levels. Output will be provided from the 00 and 12 UTC runs from the initial analysis time out to 24 hours.

The NOAA/FSL MAPS model MOLTS output will be available from 311 locations over North America. Within the LSA-NW there will be the same 101 locations as the NOAA/NCEP Eta model (Figure 3-44). These output will contain 27 surface parameters and 16 parameters at each of the 40 vertical levels. Output will be provided from each 3-hourly MAPS run from the initial analysis time out to 6 hours.

**Table 3-9 Fundamental Output Variables for the MOLTS**

**1) Identifiers**

Location identifier
Valid date/time
Latitude/Longitude/Elevation

**2) Surface Parameters**

Mean sea level pressure
Surface pressure
Skin temperature
Total precipitation in last hour
Convective precipitation in last hour
Latent heat flux
Sensible heat flux
Snow phase-change heat flux
Short-wave radiation flux downward and upward
Long-wave radiation flux downward and 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
U-wind and V-wind components at 10 m
Temperature at 2 m
Specific humidity at 2 m

**3) Atmospheric Variables at Each Model Vertical Level**

Pressure
Geopotential height
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

MOLTS Derived Sounding Output - JOSS will extract from the MOLTS output from the locations within the LSA-NW for each of the three models described above (see Figure 3-44). These output will then be processed and converted to a format similar to that used for the actual atmospheric sounding data (i.e. NWS). This will be done by stripping out the state parameters at the surface and each model level. Only the 00 hour initial analysis time will be processed. Output will be available from both the 00 and 12 UTC model analysis times. This output is provided to allow intercomparison studies. These output will be archived at JOSS.

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 Data Set (MORDS) will be 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 will 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 3-10. The output from the three models may not include all of the variables listed in Table 3-10, and this fact will be a part of the metadata provided with the specific model output. The output from each of the three models will be provided on a standard AWIPS (Advanced Weather Interactive Processing System) 212 grid (Figure 3-45) in GRIB format.

**Table 3-10 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

# 4. SPECIAL PROCESSING

This section includes summaries of some of the special processing that will occur relative to data to be collected during the LSA-NW EAOP.

## 4.1 *In-Situ*

This section discusses the quality control (QC) of the surface and precipitation composites to be created for the LSA-NW EAOP. Detailed descriptions of the components of the composite data sets are provided in Section 3. Uniform QC procedures will be applied during the compositing process. Brief descriptions of the QC processes follow.

### 4.1.1 QC of LSA-NW EAOP Surface Composites

The LSA-NW EAOP hourly surface composite will be formed by an aggregation of data sets from several surface meteorological networks (Figure 4-1). Selected parameters from each data set will be 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 will be compared to "expected values" computed using an objective analysis method adapted from that developed by Cressman (1959) and Barnes (1964). The JOSS HQC method allows 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" will be 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 is excluded); i.e.;

Where $X_e$ 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 $X_o(i)$ 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" will be 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 the possible LSA-NW EAOP normalizing factors. Table 4-2 contains the possible 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 LSA-NW EAOP data will fall within these ranges. For example, 95% of the observed station pressure values that will be flagged as "good" will be within 1.5 mb of the expected value. Values for EAOP-98 are expected to be similar to these. The significant overlap of the ranges seen in Table 4-2 is partially due to seasonal and station differences in standard deviations. The actual HQC limits applied at any particular time depend upon the dynamic nature of the particular station's parameter values over time.

*Data will never be changed, only flagged.*

HQC will only be 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 is available, its flag is applied to the station and sea level pressures. If the calculated sea level pressure can not be quality controlled, the sea level pressure quality control flag is applied to the station pressure. If the sea level pressure can not be quality controlled, the station pressure quality control flag is not overridden.

**Table 4-1 Possible Normalizing Factors Used for LSA-NW EAOP 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 Possible Ranges of HQC Flag Limit Values for the LSA-NW EAOP Surface Composites**

| Parameter | Good | Questionable | Unlikely |
|---|---|---|---|
| Station Pressure (mb) | < 1.5 | [0.7-3.9] | > 1.7 |
| Sea Level Pressure (mb) | < 1.7 | [0.5-4.3] | > 1.2 |
| Calculated SLP (mb) | < 3.9 | [0.9-9.8] | > 2.2 |
| Dry Bulb Temperature ($^oC$) | < 2.9 | [1.2-5.8] | > 2.4 |
| Dew Point Temperature ($^oC$) | < 3.2 | [1.2-6.3] | > 2.4 |
| Wind Speed ($ms^{-1}$) | < 7.4 | [3.2-13.2] | > 5.6 |
| Wind Direction ($^o$) | < 156.8 | [94.6-180.0] | > 170.5 |

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

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

The JOSS HQC scheme relies 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 LSA-NW EAOP Precipitation Composites

The LSA-NW EAOP hourly and daily precipitation composites will be formed from an aggregation of data sets from several surface precipitation networks (Figure 4-2). The schematic shows the processing steps involved in the preparation of the hourly precipitation composite. The daily composite is produced in a similar fashion except that it uses other segments of the data as described in Section 3.1.1. Each data set will be quality controlled by the use of a series of global limit checks.

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

**Table 4-3 QC Limits to be Applied to Precipitation Values for LSA-NW EAOP Precipitation Composites**

| Parameter | Good | Questionable | Unlikely |
|---|---|---|---|
| Hourly Precipitation | < 20 mm | 20-50 mm | > 50 mm |
| Daily Precipitation | < 100 mm | 100-125 mm | > 125 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, ARM, and Canadian sounding data processed by JOSS will undergo only one of the usual two-stage QC process. First, the data sets will undergo 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 has in the past been 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. This visual QC process has not been conducted

on GCIP sounding data since ESOP-96. 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 will conducted on each of the soundings and data will be automatically flagged as appropriate. They will verify that the values of each parameter are within reasonable limits for a mid-latitude warm (or cold)-season atmosphere. Only the data point under examination will be flagged. The gross limits checks that JOSS will apply to the GCIP LSA-NW EAOP sounding data sets are shown in Table 4-4. Note that those given within the table are for the warm season data only.

### 4.1.4.2 Vertical Consistency Checks

These checks will be conducted on each of the soundings and data will automatically be flagged as appropriate. They are more stringent than the gross limit checks. These checks will start at the lowest level of the sounding and compare 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 will be applied. The first group ensures that parameters that should increase/decrease do so. The second type ensures that parameters do 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 will be flagged. However, for the other checks, all of the data points used in the examination will be flagged. The vertical consistency checks that will be applied by JOSS to the GCIP LSA-NW EAOP sounding data sets are shown in Table 4-5. Note that those within the table are for the warm season only.

**Table 4-4 Gross Limit Checks Applied to GCIP LSA-NW EAOP 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 LSA-NW EAOP 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 |
| | > 1mb/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 for p < 150 mb) | P,T,RH | Q |
| | > 30 C/km (not applied for p < 150 mb) | 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

Note that this process will not be applied to the LSA-NW sounding data. It is included for informational purposes only.

Each NWS 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). Presently, JOSS is attempting to come up with an automated methodology for detecting and flagging affected sounding data.

### 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). Presently, JOSS is attempting to come up with an automated methodology for detecting and flagging affected sounding data.

# 5. DATA DISSEMINATION

Data for the LSA-NW EAOP will be 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 LSA-NW EAOP On-line Data Access

The LSA-NW EAOP data will be 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 source modules. Figure 5-1 depicts the DMSS structure. The World Wide Web (WWW) home page for GCIP and the DMSS resides at NOAA/NCDC 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 does not as yet exist.

### 5.1.1 The *In-situ* Data Source Module

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The LSA-NW EAOP *In-situ* data will be 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 data 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 LSA-NW EAOP. Additionally, LSA-NW EAOP 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 Data Source Module

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The GCIP Model Output Data 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 Data 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) 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 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 GCIP home page that provides detailed information on the MAPS model. The WWW URL for the GCIP MAPS home page is:

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

## 5.2 LSA-NW EAOP CD-ROM

A subset of the data sets that will be available through CODIAC may be published on a CD-ROM. Table 5-1 provides a summary of these proposed data sets. This list may change depending upon the requirements of the GCIP Scientific Community, Science Panels, GCIP Project Office, and the GCIP Data Management Committee. Detailed descriptions of the data sets are provided in Section 3.0. Companion software tools will be available to browse and display the data (i.e., areal plots, time series plots, altitude plots, image displays). These tools will be available for DOS, MacIntosh, and UNIX based systems.

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. Much of this information is also available via the GCIP Reference Data Set (GREDS) WWW page at:

http://nsdi.usgs.gov/nsdi/wais/water/gcip.HTML

**Table 5-1 Proposed LSA-NW EAOP CD-ROM Data Set Contents**

Surface

- LSA-NW EAOP Hourly Surface Land Composite Data
- LSA-NW EAOP Hourly Precipitation Composite Data
- LSA-NW EAOP Daily Precipitation Composite Data
- NCDC Cooperative Observer Network Data (Summary of the Day)
- USGS Streamflow Data
- USGS Reservoir Data
- NCDC SAO "Specials" Data

Upper Air

- NWS high resolution (6-sec) soundings
- NOAA Profiler Network Hourly Data (405 MHZ)

Imagery

- NOAA/RFC Stage III Daily Accumulated Precipitation Estimate Composites
- Daily 1200 UTC GOES-8 4-km Infrared Satellite Image
- Daily 2100 UTC GOES-8 2-km Visible Satellite Image
- Daily 1200 UTC GOES-8 8-km Water Vapor Image
- 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
- EROS Data Center Bi-weekly AVHRR Vegetation Composites
- MSFC 1200 UTC National Reflectivity Composite
- WSI 1200 UTC NOWRAD Composites

**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

| | |
|---|---|
| 2-D | Two Dimensional |
| 3-D | Three Dimensional |
| ABRFC | Arkansas-Red Basin River Forecast Center (NOAA) |
| AERI | Atmospherically Emitted Radiance Interferometer (UW) |
| AES | Atmospheric Environment Service (Canada) |
| AIRS | Aerometric Information Retrieval System (EPA) |
| ALERT | Automated Local Evaluation in Real Time |
| AMSU | Advanced Microwave Sounding Unit |
| ARL | Air Resources Laboratory (NOAA) |
| ARM | Atmospheric Radiation Measurement (DOE) |
| ARS | Agricultural Research Service (USDA) |
| ASCII | American Standard Code for Information Interchange |
| ASOS | Automated Surface Observing System |
| ASTER | Advanced Spaceborne Thermal Emission and Reflectance Radiometer (EOS) |
| AVHRR | Advanced Very High Resolution Radiometer |
| AWIPS | Advanced Weather Interactive Processing System (NOAA) |
| AWON | Agricultural Weather Observation Network (UW) |
| AWOS | Automated Weather Observing System |
| BDRF | Bi-Directional Reflectance Factor |
| BUFR | Binary Universal Form for Data Representation |
| CART | Clouds and Radiation Testbed (DOE) |
| CAWS | Commercial Agriculture Weather Station (University of Missouri Extension) |

| | |
|---|---|
| CBRFC | Colorado Basin River Forecast Center (NOAA) |
| CD | Compact Disk |
| CDAS | Climate Data Assimilation System |
| CERES | Clouds and the Earths Radiant Energy (EOS) |
| CLAVR | Clouds from AVhRr |
| CMC | Canadian Meteorological Centre |
| CMDL | Climate Monitoring and Diagnostic Laboratory (NOAA) |
| CoAgMet | Colorado Agriculture Meteorology (CSU) |
| COMET | Cooperative program for Operational Meteorology, Education, and Training (UCAR) |
| CRREL | Cold Regions Research Laboratory (USACE) |
| CSA | Continental Scale Area |
| CSU | Colorado State University |
| DAAC | Distributed Active Archive Center (NASA) |
| DEM | Digital Elevation Model |
| DMSP | Defense Meteorological Satellite Program |
| DMSS | Data Management and Service System (GCIP) |
| DNR | Department of Natural Resources |
| DOC | Department of Conservation |
| DOD | Department of Defense |
| DOE | Department of Energy |
| DOT | Department of Transportation |
| DSS | Data Support Services (NCAR) |
| E | East |
| EAOP | Enhanced Annual Observing Period |
| EBBR | Energy Balance Bowen Ratio (DOE) |
| ECMWF | European Centre for Medium Range Weather Forecasts |
| ECOR | Eddy Correlation (DOE) |
| EDAS | Eta Data Assimilation System (NOAA) |
| EDC | EROS Data Center (USGS) |
| EOP | Enhanced Observing Period |
| EOS | Earth Observing System (NASA) |
| EPA | Environmental Protection Agency |
| ERBE | Earth Radiation Budget Experiment |
| EROS | Earth Resources Observation Systems |

| | |
|---|---|
| ERS | European Remote Sensing Satellite |
| ESOP | Enhanced Seasonal Observing Period |
| ETM+ | Enhanced Thematic Mapper Plus |
| FAA | Federal Aviation Administration |
| FEST | Fronts Experiment Systems Test (STORM) |
| FRD | Field Research Division (NOAA/ARL) |
| FSL | Forecast Systems Laboratory (NOAA) |
| FTS | Forest Technology Systems, Incorporated |
| FWN | Fire Weather Network |
| GCIP | GEWEX Continental-scale International Project |
| GEM | Global Environmental Multiscale (AES/CMC) |
| GEWEX | Global Energy and Water Cycle Experiment |
| GHCC | Global Hydrology and Climate Center (NASA) |
| GHRC | Global Hydrology Resource Center (NASA) |
| GIDS | GCIP Initial Data Sets |
| GIF | Graphic Image Format |
| GIST | GCIP Integrated Systems Test |
| GOES | Geostationary Operational Environmental Satellite |
| GREDS | Geographic Reference Data Set (USGS) |
| GRIB | GRId point values expressed in Binary form |
| GSFC | Goddard Space Flight Center (NASA) |
| HDF | Hierarchical Data Format |
| HPCN | High Plains Climate Network |
| HQC | Horizontal QC |
| ICN | Illinois Climate Network (ISWS) |
| IGPO | International GEWEX Project Office |
| IOP | Intensive Observing Period |
| IR | InfraRed |
| IRI | Interdisciplinary Research Initiative (USGS) |
| ISA | Intermediate-Scale Area |
| ISU | Iowa State University |
| ISWS | Illinois State Water Survey |
| JOSS | Joint Office for Science Support (UCAR) |

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|---|---|
| LA | Limiting Angle |
| LaRC | Langley Research Center (NASA) |
| LMRFC | Lower Mississippi River Forecast Center (NOAA) |
| LSA | Large-Scale Area |
| LTER | Long-Term Ecological Research (NSF) |
| MAPS | Mesoscale Analysis and Prediction System (NOAA/FSL) |
| MBRFC | Missouri Basin River Forecast Center (NOAA) |
| MFRSR | Multi-Filter Rotating Shadowband Radiometer |
| MISR | Multi-angle Imaging Spectroradiometer (EOS) |
| Mn/ROAD | Minnesota Road Research Project (MnDOT) |
| MODIS | Moderate resolution Imaging Spectroradiometer (EOS) |
| MOLTS | Model Location Time Series |
| MOPIT | Measurement of Pollution in the Troposphere (EOS) |
| MORDS | Model Output Reduced Data Set |
| MRF | Medium Range Forecast Model (NCEP) |
| MSEA | Management Systems Evaluation Areas |
| MSFC | Marshall Space Flight Center (NASA) |
| MSS | Multispectral Scanner (IKONOS) |
| MVI | MODIS Vegetation Index (EOS) |
| MWR | Microwave Radiometer (DOE) |
| NADP | National Atmospheric Deposition Program |
| NASA | National Aeronautics and Space Administration |
| NC | North Central |
| NCAR | National Center for Atmospheric Research |
| NCDC | National Climatic Data Center (NOAA) |
| NCEP | National Centers for Environmental Prediction (NOAA) |
| NCRFC | North Central River Forecast Center (NOAA) |
| NDARB | North Dakota Atmospheric Resources Board |
| NDVI | Normalized Difference Vegetation Index |
| NESDIS | National Environmental Satellite, Data and Information Service (NOAA) |
| NEXRAD | NEXt generation RADar (now WSR-88D) |
| NIDS | NEXRAD Information Dissemination Service |
| NOAA | National Oceanic and Atmospheric Administration |
| NOHRSC | National Operational Hydrologic Remote Sensing Center (NOAA) |

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|---|---|
| NPA | National Precipitation Analysis |
| NPN | NOAA Profiler Network |
| NRCS | Natural Resource Conservation Service (USDA) |
| NSIDC | National Snow and Ice Data Center |
| NSSC | National Soil Survey Center (NRCS) |
| NSTL | National Soil Tilth Laboratory |
| NTN | National Trends Network |
| NW | North West |
| NWP | Numerical Weather Prediction |
| NWRFC | Northwest River Forecast Center (NOAA) |
| NWS | National Weather Service |
| OH | Office of Hydrology (NOAA) |
| ORNL | Oak Ridge National Laboratory (DOE) |
| PAR | Photosynthetically Active Radiation |
| POES | Polar Orbiting Environmental Satellite |
| PS | Panchromatic Sensor |
| PSU | Pennsylvania State University |
| QC | Quality Control |
| RASS | Radio Acoustic Sounding System |
| RAWS | Remote Automated Weather Station (USFS) |
| RFC | River Forecast Center |
| RFE | Regional Finite Element |
| ROI | Radius Of Influence |
| ROM | Read Only Memory |
| SAO | Surface Airways Observation |
| SAST | Scientific Assessment and Strategy Team (USGS) |
| SCD | Scientific Computing Division (NCAR) |
| SDSM | Satellite Data Source Module (GCIP) |
| SDTS | Spatial Data Transfer Standard |
| SGP | Southern Great Plains (DOE) |
| SIROS | Solar and Infrared Radiation Observing System (DOE) |
| SIRS | Solar Infrared Radiation Station (DOE) |
| SLP | Sea Level Pressure |

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| SMOS | Surface Meteorological Observation Station (DOE) |
| SM/ST | Soil Moisture/Soil Temperature (USDA/NRCS) |
| SNOTEL | Snow Telemetry (USDA/NRCS) |
| SRRB | Surface Radiation Research Branch (NOAA/ARL) |
| SSA | Small-Scale Area |
| SSI | Surface Systems, Incorporated |
| SSM/I | Special Sensor Microwave Imager |
| STATSGO | State Soil Geographic Database (USDA) |
| STORM | STorm-scale Operational and Research Meteorology |
| SURFRAD | SURFace RADiation budget network (NOAA/ARL) |
| SW | South West |
| SWATS | Soil Water and Temperature System (DOE) |
| SWE | Snow Water Equivalent |
| SWIR | Short Wave IR |
| TBD | To Be Determined |
| TDR | Time Domain Reflectometry |
| TIR | Thermal IR |
| TIROS | Television and Infrared Observation Satellite |
| TOA | Top of Atmosphere |
| TOVS | TIROS Operational Vertical Sounder |
| UCAR | University Corporation for Atmospheric Research |
| UM | University of Minnesota |
| URL | Uniform Resource Locator |
| US | United States |
| USACE | United States Army Corps of Engineers |
| USAF | United States Air Force |
| USBR | United States Bureau of Reclamation |
| USDA | United States Department of Agriculture |
| USFS | United States Forest Service |
| USFWS | United States Fish and Wildlife Service |
| USGS | United States Geological Survey |
| UTC | Universal Time Coordinated |
| UV | Ultraviolet |
| UW | University of Wisconsin |

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|---|---|
| VIS | Visible |
| VNIR | Very Near IR |
| WCRP | World Climate Research Programme |
| WDT | Wisconsin Dense Till (USDA/NRCS) |
| WMO | World Meteorological Organization |
| WSI | Weather Services International |
| WSR-88D | Weather Surveillance Radar - 1988 Doppler |
| WV | Water Vapor |
| WWW | World Wide Web |