MCS Electrification and Polarimetric Radar Study

Operations Plan

May 6, 1998

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1. Introduction

The MCS Electrification and Polarimetric Radar Study (MEaPRS) experiment will be hosted by the National Severe Storms Laboratory (NSSL) and conducted over western and central Oklahoma from May 15 through June 15, 1998. In addition to NSSL, other institutions involved in MEaPRS include the Atlantic Oceanographic and Meteorological Laboratory (AOML), Colorado State University (CSU), the University of Mississippi (UM), the University of Oklahoma (OU), New Mexico Tech University (NMTECH), Texas A&M University (TAMU), the Cooperative Institute for Mesoscale Meteorological Studies (CIMMS), the Cooperative Institute for Applied Meteorological Studies (CIAMS), the Los Alamos National Laboratory (LANL), the National Center for Atmospheric Research (NCAR), NASA/Marshall Space Flight Center (MSFC), NOAA Aircraft Operations Center (AOC), and the NWS/NCEP/Storm Prediction Center (SPC). This document is the Operations Plan for the experiment. It is intended to assist in the training of project participants and to serve as a guide for field operations once the experiment begins.

1.1 Primary Goals of MEaPRS

As stated in the title, the two primary goals of MEaPRS are to investigate MCS electrification processes and improve understanding of polarimetric radar measurands. A brief overview of these goals are presented here. A more complete discussion of overall scientific objectives and the MEaPRS experimental design are presented later in this document.

MCS Electrification:

In recent years, many studies have addressed the electrification of midlatitude MCSs. Balloon-borne electric field meter (EFM) measurements combined with winds derived from airborne and ground-based Doppler radar measurements have lead to the development of conceptual models of MCS electrification. From these studies, two specific hypotheses for stratiform electrification have evolved: 1) advection of charge from the convective line, and 2) local charge generation by microphysical interactions within the stratiform region. Despite recent advances, however, a general lack of comprehensive kinematic, microphysical, and electrical data sets has limited further progress in the understanding of MCS electrification processes. In particular, questions as rudimentary as to whether the majority of stratiform charge is advected from the convective line or generated locally within the stratiform region (or even whether the necessary conditions for local stratiform charging are met), remain unanswered. Observations of different but repeatable electrical structures that appear to be related to MCS precipitation type raise further questions regarding possible interactions between MCS airflow, thermodynamic, microphysical, and electrical structures and, subsequently, their combined relationship to the MCSs evolution.

During MEaPRS, coordinated balloon-borne EFM launches will be made from two NSSL mobile laboratories. In addition, balloon-borne instrumentation to measure particle charge, lightning field changes, x-ray emissions, and hydrometeor habits will provide complementary information unavailable in previous MCS electrification field projects (e.g., COPS89 and COPS91). During the collection of
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electrical data sets, the MCSs concomitant kinematic and microphysical structures will be documented by the NOAA P-3 aircraft while additional information on the MCSs microphysical characteristics will be provided by polarimetric radar.

Polarimetric Radar Studies:

Advances in polarimetric radar in recent years have shown great promise at improving knowledge of the microphysical characteristics of convective clouds. In particular, research already completed has demonstrated that polarimetric radar measurements can lead to improvements in rainfall estimation, determination of ice water content, and discrimination of hail size. Proper interpretation of polarimetric signals, however, requires quality in-situ microphysical measurements. Whereas many studies have already investigated the polarimetric signatures of convective cells, relatively few have investigated the stratiform precipitation associated with MCSs. In addition to improved rainfall estimation in these systems, the development of polarimetric techniques for remotely sensing MCS microphysical structure may have other benefits such as improved microphysical initializations of mesoscale models, and improved calibration of precipitation rates from non-polarimetric radars (such as the NWS WSR-88D). The importance of this goal is further emphasized by the National Weather Service’s long-term commitment to exploring polarimetric capabilities for the WSR-88D radar design. Development of a new polarization scheme that is compatible with current scanning strategies is currently underway at NSSL on a prototype WSR-88D radar provided by the NWS.

During MEaPRS, a NOAA P-3 aircraft will collect in-situ microphysical data with which to verify signatures of particle types as provided by the Cimarron polarimetric radar. While data sets detailing MCS microphysical structure have been collected during previous research projects (e.g., COPS89 and COPS91), improvements made to both the P-3 microphysical instrumentation and the Cimarron radar’s polarimetric capabilities will together provide more detailed microphysical and polarimetric information in MEaPRS than was possible in previous projects. The microphysical data obtained from aircraft will be combined with ground-based observations by mobile laboratory crews, disdrometers, and mesoscale and microscale raingauge networks to improve radar estimation of rainfall rates, ice water contents, and to develop automated techniques for classifying and quantifying the microphysical characteristics of MCS stratiform clouds.

1.2 Ancillary Goals of MEaPRS

Given the broad expertise of the MEaPRS Principal Investigators (PIs), several ancillary objectives will also be investigated during the experiment. These primarily include topics that address MCS dynamic and microphysical structures, and investigations that focus on the characteristics of sprites. In most cases, data collection in fulfillment of these objectives will compliment the data needs of the primary research goals (i.e., MCS electrification and polarimetric radar studies). It is expected that knowledge gained from MEaPRS will both advance basic science goals and have potential operational applications.

1.3 Adjunct Experiments

Several adjunct experiments will be coordinated with MEaPRS operations. These include 1) an MCS forecasting experiment conducted by the NSSL Mesoscale Application Group, 2) the SubVORTEX-RFD experiment to document the origin and evolution of the supercell Rear Flank Downdraft, and 3) the Satellite-Radar Study of Storm Top Plumes experiment to improve understanding of satellite-observed cloud top structures and their link to internal storm processes. When possible, MEaPRS operations will be coordinated with these adjunct experiments in order to collect more comprehensive data sets.
More information on MEaPRS and the adjunct experiments can be found on the WWW at:

**MEaPRS:**
http://www.nssl.noaa.gov/~schuur/meaprs/meaprs.html

**SubVortex-RFD:**

**Satellite-Radar Study of Storm Top Plumes:**
http://www.nssl.noaa.gov/~schuur/meaprs/rabin.html
2. Project Overview

The primary research platform used in MEaPRS will be the NOAA P-3 aircraft. In addition, three mobile laboratories (Rust, 1989) from the Joint Mobile Research Facility (JMRF) will be deployed to locations throughout western and central Oklahoma to launch balloon-borne electric field meters (EFMs) into developing MCSs. Occasionally, these balloon launches will also include instrumentation to measure particle charge and size information, in-situ microphysical data along the balloon path, lightning field changes, and x-ray emission associated with cloud-to-ground (CG) and intracloud (IC) lightning flashes.

NSSL’s Cimarron radar (hereafter referred to as Cimarron) will provide polarimetric and Doppler wind measurements within 100 km of the radar site (Fig. 1). In addition, Cimarron data will be combined with data from the NWS’s Twin Lakes operational (KTLX) and Operational Support Facility training (KCRI) WSR-88D radars to provide dual-Doppler coverage over central Oklahoma. Other observational data sources to be utilized during MEaPRS include the National Lightning Detection Network (NLDN), NWS WSR-88D radars from throughout the experimental domain, NWS operational soundings, the ERL demonstration profiler network, and the Oklahoma mesonet. The approximate locations of the fixed-base observational facilities and range of the mobile research facilities are shown in Fig. 1.

Figure 1: Approximate locations of the NSSL Cimarron radar (CIM), NWS WSR-88D radars, ERL demonstration profiler networks sites, and NWS radiosonde sites with respect to the MEaPRS operational domain. Circles represent 2 hour one-way ferry and 0.5 hour one-way ferry of the NSSL mobile laboratories and NOAA P-3 aircraft, respectively. Cross-hatching represents 100 km Doppler radar coverage by CIM, KTLX, and KCRI.
As stated earlier, the two overarching goals of MEaPRS are to investigate the electrical properties and polarimetric measurands of midlatitude MCSs. Nevertheless, the observational capabilities of MEaPRS also provide a unique opportunity to investigate several ancillary objectives. As such, and to facilitate a comprehensive presentation of all MEaPRS objectives in the experiment design (presented in detail in Section 8), the observational domain for MEaPRS is partitioned into three regions for the purpose of organizing the various research objectives. These three regions are specified as being: I) outside of Cimarron range, II) within 100 km of Cimarron but outside of dual-Doppler coverage, and III) within dual-Doppler coverage. The approximate locations of these three regions with respect to the ground-based radar coverage is shown in Fig. 2.

**Figure 2:** Approximate locations of Regions I, II, and III (see text), with respect to the MEaPRS observational domain. Dark shading depicts dual-Doppler coverage by the Cimarron-KTLX radar pair (bounded by 22 degree intersection angles); cross-hatching depicts the 100 km range of optimal Cimarron polarimetric coverage.

In region I, which is out of the ground-based radar coverage required to accomplish much of the project’s electrical and polarimetric goals, efforts will be made to address the scientific goals that are best described as MCS dynamics. In region II, which is within 100 km of Cimarron but outside of dual-Doppler coverage, more emphasis will be placed on the project’s microphysical, polarimetric, and electrical objectives. Finally, in region III, where quality ground-based dual-Doppler radar coverage exists, the P-3 will be given more flexibility in its flight patterns, but emphasis will be placed on collecting high-quality comprehensive data sets that address the electrical needs of MEaPRS. It should be remembered that this observational domain partitioning represents an optimal plan for obtaining data sets in support of all MEaPRS objectives. Data collection in support of the projects primary goals (e.g., electrification and polarization), however, will take precedence. As such, the PIs will be given the flexibility to occasionally extend electrical data collection to locations outside of Regions I and II (with P-3 support) in order to assure that sufficient data sets addressing the primary research goals of MEaPRS are collected.
In addition to data from the NLDN, a new three-dimensional VHF total lightning mapper will also be operated during MEaPRS. The system is an expanded, deployable version of the Lightning Detection and Ranging (LDAR) system being operated at Kennedy Space Center. Sites for ten stations have been chosen northwest of the NSSL Cimarron radar, spread over an area 60 km in diameter centered near Kingfisher, Oklahoma. Each station will record the arrival time of the peak lightning radiation signal within successive 100 microsecond windows. The clock at each station will be synchronized within 50-100 nanoseconds to an accurate GPS signal. The arrival times at the different stations will be analyzed using a least-squares program to obtain the spatial structure and temporal development of each lightning discharge. Over or near the network the location accuracy for well-defined events will be on the order of 100-200 m; for more distant discharges the network determines primarily the azimuth and range of the sources, out to about 100-150 km. The raw data will be recorded on digital audio tape at each site and retrieved as soon as possible after each storm day. Data for a given storm (or part of a storm) will be combined onto a CD-ROM and segments will be quickly processed to verify that each station is operating properly. The complete data sequence will be automatically processed as time permits.

Forecasting and nowcasting activities for MEaPRS will be conducted from the shared NSSL/SPC Science Support Area (SSA), the logistics of which will be addressed elsewhere in this document.
3. Scientific Objectives

The scientific objectives presented here are grouped into four categories (dynamics, microphysics, polarization, and electrification) and are listed in an order that loosely follows the observational domain partitioning of the previous section (see Fig. 2). That is, they are *not* necessarily presented in order of their importance to the overall project objectives, but rather the order that they will likely be addressed in a typical P-3 mission. Of course, it is beyond the capabilities of the project to address all scientific goals on each mission. Therefore, efforts will be made to assure that data collection requirements are met for all scientific objectives at some point during the project, which is likely to include at most six P-3 missions. Specific experiment designs that include aircraft flight patterns and preferred locations for the ground-based mobile facilities are presented in section 8.

Whereas all of the scientific objectives listed here have very specific data collection requirements, they should not be considered mutually exclusive. At times, data requirements for several objectives may be fulfilled simultaneously. Furthermore, it should be remembered that data collected in support of one objective may be useful in the interpretation of other data sets. When appropriate, these potential interrelationships will be listed.

3.1 MCS Dynamics

3.1.1 OBJECTIVE D1: Vorticity balance at the leading edge of MCS outflow

*PROCESS TO BE STUDIED:* Rotunno et al. (1988) theorized that the evolution of squall lines is in part controlled by a balance in vorticity about a horizontal axis parallel to the line. The vorticities involved in this balance are those contained in the low-level outflow to the rear of the gust front and in the low-level shear profile of the environmental wind ahead of the system. The theory predicts that when a quasi-balance exists between these two vorticities of the opposite sign, updrafts at the gust front are upright and the squall line convection exists in a strong, mature state. When, however, the vorticity in the outflow grows to be stronger than in the environmental shear, the updrafts tilt rearward, and the system evolves to a weaker state. Rasmussen and Rutledge (1993) examined a number of squall lines and suggested that there is another stable state where tilted updrafts exist for an extended period.

*MEASUREMENT REQUIREMENTS:* The P-3 will collect radar data at mid-levels of the stratiform region in FAST sector scanning mode while flying at an altitude of 1 km AGL and a location approximately 10-20 km ahead of the convective line. Repeated flight legs will yield a complete scan of a portion of the convective line at 15 minute intervals. During P-3 data collection, a mobile laboratory crew will launch soundings at a location approximately 40 km ahead of the line once per hour. In the event that mobile labs are unavailable, the above-described soundings will be taken using P-3 dropsondes or P-3 low-level in-situ soundings. These measurements would ideally be continued for several hours during the mature and dissipating stages of an MCS.

3.1.2 OBJECTIVE D2: Morphology and vector vorticity dynamics of Mesoscale Convective Vortices

*PROCESS TO BE STUDIED:* Mesoscale Convective Vortices (MCVs) are potentially dominant MCS circulations. There are already a few direct observations of MCVs on approximately the 100 km length scales (e.g., Jorgensen and Smull, 1993; Brandes and Ziegler, 1993). From those studies, it is believed that mid-level horizontal, solenoidally generated anti-streamwise vorticity is tilted into vertical vorticity within the mesoscale downdraft and subsequently intensified by stretching. While other vortex-genesis mechanisms have been postulated (chiefly the vertical stretching of pre-existing vertical relative and earth-spin vorticity), the above hypothesis is tested here since 1) its basic
elements may be found in all MCSs and, 2) the solenoidal mechanism offers a potentially abundant source of ambient mesoscale rotation.

**MEASUREMENT REQUIREMENTS:** The P-3 will collect radar data in FAST mode in up to full 360 degree scans. Data from ground-based radars, including Cimarron and any WSR-88D radars in proximity to the MCS, will be incorporated into the analysis. In-situ soundings and transects of state variables within the MCS (as provided by MCLASS soundings and the P-3, respectively) are also required. To complement these data sets, additional data needs include visible and infrared satellite imagery, NWS surface network, soundings, and ERL demonstration profiler network observations. Other desirable data include Oklahoma and CASES mesonet data and ARM surface and upper air network observations.

**3.1.3 OBJECTIVE D3:** Evolution of MCS convective structure

**PROCESS TO BE STUDIED:** Several studies have examined the temporal and spatial variability of convective structure in relation to scale interactions and mesoscale storm dynamics. For example, Rasmussen and Rutledge (1993) have shown that the convective regions of symmetric MCSs often evolve rapidly from a vigorous state of deep, vertically oriented convection to a less intense, shallower, and more horizontally tilted circulation. Furthermore, in asymmetric MCSs, it has been found that interaction between mesoscale outflow from a mid-level mesovortex may affect both the strength and evolution of convection. Understanding the dynamics associated with MCS convective line evolution is important towards understanding mass flux, microphysical evolution, and electrification processes in MCSs.

**MEASUREMENT REQUIREMENTS:** The P-3 will obtain volume radar data in FAST mode in up to full 360 degree scans. A series of flight legs will be flown at a location approximately 15-20 km behind the convective line and an altitude of 4-5 km. The straight-and-level flight legs along and parallel to the back of the convective region will be approximately 30 minutes in duration (200 km in length). Simultaneous data collection by the P-3 microphysical instrumentation, Q-probe, and coordination with balloon-borne EFM launches will allow these data to be useful for scientific objectives that seek to examine MCS airflow, microphysics, and electrical interactions.

**3.1.4 OBJECTIVE D4:** The relation of pressure and buoyancy forces to mesoscale evolution in the stratiform region of MCSs

**PROCESS TO BE STUDIED:** An analysis of wind fields derived from frequent dual-Doppler radar observations can provide information on the important forces associated with MCS airflow evolution (Matejka, 1991). In particular, acceleration and deceleration of the primary branches of the mesoscale circulation in the stratiform region are likely the result of a combination of factors, including but not limited to heating and cooling resulting from microphysical processes. By decomposing these forces through thermodynamic retrieval techniques, it is possible to develop a better understanding of the behavior and evolution of MCSs.

**MEASUREMENT REQUIREMENTS:** Repeated volume scans with Cimarron, WSR-88D, and, if available, the P-3 tail radar for recovery of four-dimensional wind fields will be conducted for all locations behind the convective line. At least one thermodynamic sounding through the stratiform region in the analysis area is required to anchor the thermodynamic retrieval. Passage of the system through the ground-based radar analysis region is required to ensure that a sufficiently large area of analysis exists. Minimum requirements for ground-based radar scans are one 6-minute volume scan in one dual-Doppler lobe every 12 minutes or one 6-minute volume scan in each of the two dual-Doppler lobes every 18 minutes. Successive soundings (60-90 minutes apart) are desirable if the weather remains within the analysis region long enough.
3.2 MCS Microphysics

3.2.1 OBJECTIVE M1: Microphysical fluxes from the convective line

PROCESS TO BE STUDIED: Relatively few microphysical data sets have been collected in midlatitude MCSs. In probably the most comprehensive study to date, Yeh et al. (1991) found that hydrometeor concentrations are as much as 4 to 6 times higher in the transition zone than in the stratiform region and that the mean size of the hydrometeors in the transition zone are smaller by as much as a factor of two. It is clear, however, that a better understanding of mass fluxes, the evolution of hydrometeors as they advect into the mesoscale updraft, and stratiform region precipitation processes in general will require improved kinematic and microphysical measurements.

MEASUREMENT REQUIREMENTS: The P-3 will collect microphysical data at six flight levels behind the convective line. Each flight leg will be approximately 10 minutes in duration (75 km in length), and will be flown at a location approximately 10-15 km behind the region of intense convection. Ideally, the legs will be flown at temperatures of 5, 0, -5, -10, -15, and -20°C (appropriate flight levels in kft will be computed prior to P-3 takeoff). If possible the entire pattern, which is approximately 60 minutes in duration, will be repeated 1 hour after completion of the first set of flight legs in order to document the evolution of fluxes with time. Simultaneous tail-Doppler radar data collection by the P-3 aircraft (scanning in FAST continuous mode) will provide horizontal and vertical motions in the near vicinity of the hydrometeor data collection. Measurements of particle charge by the P-3 Q-probe will provide information on charge advection rates. Where feasible, these flight legs will also be coordinated with balloon-borne EFM launches and possibly also PPI sector scans by Cimarron.

3.2.2 OBJECTIVE M2: Vertical profiles of microphysical structure

PROCESS TO BE STUDIED: Willis and Heymsfield (1989) investigated the vertical microphysical structure through the radar bright band of a midlatitude MCS. The results of their study, which found increased aggregate and small ice crystal concentrations at location immediately above the melting level, have potentially important implications towards understanding MCS electrical structures (i.e., Schuur, 1997). Very little microphysical data, however, has been collected at locations higher up in the stratiform cloud. Improved measurements of MCS kinematic (horizontal and vertical motion) and microphysical structures promises to provide insight into stratiform precipitation processes and also aid in the interpretation of MCS electrical measurements.

MEASUREMENT REQUIREMENTS: The P-3 will conduct a series of spiral ascents/descents to document the vertical microphysical structure of the stratiform cloud. These ascents/descents will only be conducted within the ground-based dual-Doppler coverage to assure that good quality vertical motion data is obtainable (vertical motions will also be computed from the P-3 tail Doppler data using the “purl” technique described by Mapes and Houze, 1995). When possible, the microphysical data will be collected between the heights of 5 and 23 kft using an ascent/descent rate of 1000 ft min⁻¹. It is imperative that information on microphysical habits are obtained along with good quality measurements of cloud liquid water contents. The P-3 spiral ascents/descents will be coordinated with simultaneous balloon-borne EFM launches and PPI sector scans by Cimarron.

3.2.3 OBJECTIVE M3: Hydrometeor origins and evolution in MCS stratiform regions and their relation to polarimetric signatures

PROCESS TO BE STUDIED: Physical explanations of the observed precipitation pattern in the stratiform region of MCSs have been proposed by several researchers (Bartels et al., 1997). From those studies, it is clear that both preferred advection of hydrometeors from the convective line and their subsequent growth in the mesoscale updraft are important towards understanding observed precipitation patterns. By closely examining the trajectories and comparing their growth with polarimetric radar signatures, it might be possible to greatly improve understanding of precipitation processes in stratiform clouds.
MEASUREMENT REQUIREMENTS: Repeated volume scans with Cimarron, WSR-88D, and, if available, the P-3 tail radar for recovery of four-dimensional wind fields will be conducted for all locations behind the convective line. In-situ P-3 sampling of precipitation hydrometeors in the snow above the melting band across the main stratiform region rain shaft and in the rain below are desirable. Passage of the system through the ground-based radar analysis region (Region III) is required to ensure that a sufficiently large area of analysis exists. Minimum requirements for ground-based radar scans are one 6-minute volume scan in one dual-Doppler lobe every 12 minutes or one 6-minute volume scan in each of the two dual-Doppler lobes every 18 minutes. P-3 in-situ sampling is desirable but not required; if performed, minimum requirements are one horizontal leg perpendicular to the convective zone in the rain below the melting zone; the leg should traverse the main stratiform region rain shaft and extend several tens of kilometers into the weaker precipitation ahead and behind.

3.2.4 OBJECTIVE M4: Balloon-borne microphysical observations

PROCESS TO BE STUDIED: Miloshevich and Heymsfield (1997) have recently developed a balloon-borne cloud particle replicator for measuring vertical profiles of cloud microphysical properties. Results from initial test flights indicate that the replicator accurately measures small cloud particles (< 100 µm in diameter), which are undetectable or poorly resolved by aircraft optical array probes. Since this size of hydrometeor is important for cloud electrification processes, it is clear that a balloon-borne cloud particle replicator could provide valuable supplementary information on the concurrent microphysical and electrical characteristics of stratiform clouds.

MEASUREMENT REQUIREMENTS: The cloud particle replicator will be flown on a selected number of balloon flights along with an EFM and/or other electrical instrumentation. During the balloon flight, the P-3 will conduct either a spiral ascent or descent over the balloon launch location to document the larger hydrometeor sizes. Given the importance of collecting simultaneous good quality aircraft microphysical data, these flights will typically be conducted over central Oklahoma.

3.3 Polarimetric Radar Studies

3.3.1 OBJECTIVE P1: Verification of hydrometeor classification/quantification algorithm

PROCESS TO BE STUDIED: In recent years, polarimetric radar measurements have shown great promise at distinguishing hydrometeor types and amounts. In particular, some studies (i.e., Straka and Zrnic, 1993; Aubagnac and Zrnic, 1995) have employed algorithms using fuzzy logic to classify and quantify hydrometeors. Work is currently being conducted at NSSL to refine the above identification procedures. After careful testing, these algorithms promise to provide more accurate automated estimation of rainfall amounts, snowfall rates, hail size, and possibly also aircraft icing conditions. It will also have potential skill at identifying highly electrified portions of the cloud by indicating regions of aligned ice crystals. In-situ microphysical data, however, are needed to better interpret the polarimetric measurands and to test the algorithm’s overall performance.

MEASUREMENT REQUIREMENTS: The P-3 will conduct flight legs within both the ice and water regions of the stratiform cloud. Additionally, the deployment of disdrometers within 100 km of Cimarron range will assist in the analysis of polarimetric measurands. Mobile laboratory crews will assist by documenting hail sizes. During aircraft data collection, Cimarron will scan in PPI mode and, occasionally, in RHI mode when regions of particular interest have been identified (the scanning strategies for the PPI and RHI modes are described elsewhere in this document). When possible, flight legs will be flown along a path that follows a radar beam (when scanning in RHI mode), thereby allowing for a more direct comparison of polarimetric measurands and microphysical measurements.
3.3.2 OBJECTIVE P2: Polarimetric Radar Measurements of Ice Water Content

PROCESS TO BE STUDIED: The weakness of current methods for ice water content (IWC) determination from reflectivity factor measurements is in the fact that the radar reflectivity is a product of IWC and average mass of the scatterers. Thus one more independent measurement is needed for estimating IWC. Such measurement can be provided by a polarimetric radar. Theoretical basis for polarimetric IWC estimation has been established in two recent studies: Vivekanandan et al (1994) and Ryzhkov et al (1997). These studies suggest the use of specific differential phase or Kdp in combination with differential reflectivity Zdr. Polarimetric radar observations of thunderstorm anvils and ice portions of stratiform clouds show that oriented ice crystals with IWC exceeding 0.1 g m\(^{-3}\) produce pronounced polarimetric signatures at 10 cm wavelength. Kdp values can reach 0.8 deg km\(^{-1}\) in the zones of high crystal concentration. Transition from crystals to aggregates or graupel is accompanied by a decrease in both polarimetric variables.

MEASUREMENT REQUIREMENTS: Standard PPI radar scans will be used to identify the zones of interest (those with elevated Kdp and Zdr) and to establish azimuthal intervals for more focused search in the regime of sector or RHI scanning of these areas. RHI scans in the series of adjacent azimuths are necessary to establish the link "ice-aggregates-melting layer-precipitation" in vertical cross-sections. Sector horizontal scanning in certain interval of elevation angles is mostly suitable for the comparison with the in-situ aircraft data. Since expected magnitudes of Kdp are quite low, larger dwell times and larger spatial averaging are required. Recommended number of radar pulses to be averaged is 128 or 256.

3.3.3 OBJECTIVE P3: Polarimetric Radar Measurements of Rainfall.

PROCESS TO BE STUDIED: Radar polarimetric method for precipitation estimation based on specific differential phase Kdp exhibits several advantages over conventional R(Z) algorithm (Ryzhkov and Zrnic’, 1996). Extensive studies of the performance of the R(Kdp) algorithm show that in some situations Kdp-based estimates of rainfall can be biased, especially at low rain rates. The most likely causes of these biases are 1) the uncertainty of the actual raindrop shape, and 2) variability of drop size distributions. Both factors mostly affect the R(Kdp) relation for light precipitation. A newly developed method based on the combined use of Kdp and differential reflectivity Zdr (Ryzhkov and Zrnic’, 1995) mitigates some of the uncertainties due to these factors. Optical array probes on the P-3 aircraft, as well as 2D-video disdrometers on the ground (Hubbert et al., 1997), can provide essential in-situ information about actual drop size distributions and raindrop shapes. Raindrops fallspeeds obtained from the P-3 radar will also assist in the interpretation of polarimetric signatures.

MEASUREMENT REQUIREMENTS: Standard PPI scans for Cimarron must include elevation angles of 0.0, 0.5 and 1.5 deg, with the optimal radar dwell time corresponding to 128 horizontal-vertical pulse pairs. The antenna rotation rate must be within the interval between 5 and 7 deg s\(^{-1}\). Aircraft passes below the bright band in the stratiform region of precipitation are highly desirable. Two disdrometers will be situated in two locations: Norman and Purcell. The mesonet raingauge data will be available in digital format in the areas of interest. The micronet raingauge data (ARS Little Washita River basin network) will also be useful for analysis.

3.3.4 OBJECTIVE P4: Orientation of ice crystals in high electric fields

PROCESS TO BE STUDIED: Hendry and McCormick (1976) first identified radar signatures associated with the orientation of hydrometeors in thunderstorms by strong electric fields. More recently, Metcalf (1995) demonstrated a tendency for ice crystals in the upper levels of convective clouds to be associated with a distinct negative Kdp signature (of up to -0.6° km\(^{-1}\)). Since then, several others have found similar regions of oriented ice crystals and, in at least one case, have related the feature to the occurrence of strong positive CG lightning flashes. (e.g., Carey and
Rutledge, 1996). Furthermore, little is known of the electric field magnitudes necessary for the vertical ice crystal alignment or the dominant hydrometeor habit and size.

**MEASUREMENT REQUIREMENTS:** Regions of upper-level, negative K_{dp} will be identified by Cimarron PPI scans. At the nearest opportunity (usually after completion of the PPI volume scan), Cimarron scanning will then be switched to RHI mode and an approximately 20° wide sector that encompasses the region of negative K_{dp} will be scanned (the scanning strategies for the PPI and RHI modes are described elsewhere in this document). In a best case scenario, a balloon-borne EFM profile will also be obtained in the vicinity of the oriented crystals to determine the magnitude of the electric fields. Given the somewhat transient nature of these features, it is understood that it will be difficult to plan the location of these EFM flights ahead of time. Simultaneous microphysical data collection by the P-3 aircraft will document the dominant ice crystal habit and size in the vicinity of the negative K_{dp} signatures.

### 3.4 MCS Electrification

#### 3.4.1 OBJECTIVE E1: MCS electric field measurements

**PROCESS TO BE STUDIED:** Electrical studies of MCSs have shown that stratiform clouds are highly electrified more than one hundred kilometers from the main convective region (Hunter et al. 1992; Stolzenburg et al., 1994). There is also a documented tendency for the stratiform region to exhibit one of two distinct types of charge structure that appear to be related to MCS precipitation type (Marshall and Rust, 1993). Recent studies indicate that charge advection may be important at upper levels in the stratiform region, while in-situ charging mechanisms (such as non-inductive collisional charging, melting charging, inductive collisional charging, and drop breakup charging) may be important at lower levels. Current conceptual models, however, are based on a relatively small number of data sets, pointing towards a need for more comprehensive observations.

**MEASUREMENT REQUIREMENTS:** At least six EFM soundings will be launched into the following regions of each MCS: convective updraft, convective core, transition zone, stratiform precipitation region, and enhanced secondary band. In the best case scenario, EFMs will be launched in one of the dual-Doppler lobes to obtain high temporal resolution data on convective cell kinematic evolution, and microphysical data (as measured by P-3 descents/ascents). Multiple launches will be made along a line approximately perpendicular to system movement in MCSs with symmetric organization, and in the portion of the convective region that is approximately upstream of the enhanced secondary band in the stratiform precipitation region of MCSs with asymmetric organization, with the system-relative sounding locations moving rearward with time. When outside of dual-Doppler range, the P-3 will fly approximately 15 minute flight legs to document the kinematic structure and evolution in the vicinity of the EFM launch. When possible, polarimetric data from Cimarron will be combined with the in-situ electrical and microphysical measurements.

#### 3.4.2 OBJECTIVE E2: Interaction of MCS kinematic, microphysical, and electrification processes

**PROCESS TO BE STUDIED:** A distinct tilting of convection is often noted with MCS evolution. Associated with this transition, the stratiform region typically intensifies rapidly as the convective circulation results in enhanced advection of hydrometeors rearward. Billingsley and Biggerstaff (1994) noted that, as the convective circulation weakened, there was a decrease in the CG lightning flash rate in the convective region, with a lag of approximately 20 minutes occurring between the peak in area-averaged vertical motion and the peak in CG lightning. Although it is not clear how dominant charge advection is in terms of producing the electric field observed in stratiform regions, it is clear that the vertical profile of the rearward mass flux varies with time.

**MEASUREMENT REQUIREMENTS:** Data collected in fulfillment of objective D3 will be combined with data from coordinated EFM launches and CG lightning data from the NLDN to investigate the evolution of convective structure, charge advection, and CG lightning rates. In addition to Doppler
radar data, the P-3 will collect microphysical and Q-probe data on each flight leg. Data collected in support of objective M1, when coordinated with EFM launches, will also be useful in addressing this objective. If available, data from a total lightning mapper will be combined with the above data sets to improve understand of the origin and propagation of stratiform lightning discharges.

3.4.3 OBJECTIVE E3: Microphysical structure of electrified stratiform clouds

PROCESS TO BE STUDIED: In an analysis of charge profiles from many MCSs, Marshall and Rust (1993) found that MCSs appear to have distinct, but apparently repeatable, stratiform electrical structures. They speculated that the underlying cause for this repeatability might be related to MCS flow structure and microphysics. In a more detailed examination of some of the same profiles, Schuur (1997) found apparent relationships between charge transition levels and important microphysical regions. More specifically, Schuur found an apparent relationship between deep mesoscale updrafts, water saturated conditions, dendritic growth, and intense charge transitions near -12°C. The actual source of the charge, however, remains unknown.

MEASUREMENT REQUIREMENTS: Data collected in fulfillment of objective M2 will be combined with data from coordinated EFM launches to investigate the relationship between vertical microphysical and electrical structures. Excellent cloud particle imagery, particle charge data, cloud LWC, and three-dimensional wind fields are required. Since this objective requires the P-3 to conduct spiral descents, wind data will be provided by the ground-based radar; profiles of vertical motion and hydrometeor fallspeed will also be computed from the P-3 tail Doppler data using the “purl” technique described by Mapes and Houze (1995). During aircraft and balloon-borne data collection, Cimarron will conduct PPI (and occasional RHI) scans to map the vertical polarimetric characteristics of the MCS stratiform region.

3.4.4 OBJECTIVE E4: X-ray and electric field change measurements

PROCESS TO BE STUDIED: X-ray production appears to be associated with strong electric fields in thunderstorms. These fields are thought to create electron avalanches seeded by energetic cosmic-ray electrons that runaway in the electric field. Runaway electrons are those electrons that gain more energy from the electric field than is lost to interactions with the atmosphere. Runaway electron theories have been advanced to explain lightning initiation as well as newly discovered phenomena such as sprites, in the upper atmosphere above MCSs. Electric-field changes caused by lightning are well known and well characterized as observed at ground level, but only a very limited number of observations of field changes with bandwidth greater than a few tens of Hz have been made at altitude either in or above storms. The field-change observations we expect to obtain will allow us to test hypothetical mechanisms for sprites and jets and, we hope, to discriminate between unipolar and bipolar models advanced for the leader/return stroke processes in lightning.

MEASUREMENT REQUIREMENTS: Instruments for these objectives will fly on 1200 to 1500g meteorological balloons. Some x-ray flights will be made on balloons with EFMs and radiosondes. Other x-ray instruments will be flown with the field change instrument without radiosondes. All x-ray detectors will have GPS receivers to determine instrument location and altitude. Some long-duration field-change/x-ray flights will be made so that the instruments will float above a storm long enough to gather data relevant to the occurrence of sprites and blue jets. Optical observations of sprites and jets will be made by collaborators from New Mexico, Colorado, and possibly Nebraska. Long duration flights will number 1-3 per storm as conditions allow.

3.4.5 OBJECTIVE E5: Electrical structure of an MCSs southernmost convective cell

PROCESS TO BE STUDIED: The southernmost cell in a convective line often exhibits electrical characteristics that are markedly different from those in other cells. Such cells are also interesting dynamically, in that they tend to produce the most severe weather and be the strongest cells in the convective line. The apparent unique relationship between the dynamics and electrification of these convective cells, however, are poorly understood.
**Scientific Objectives**

**MEASUREMENT REQUIREMENTS:** In coordination with other objectives, the P-3 will conduct a flight leg that extends just beyond the southernmost cell and then conduct an additional leg that extends along the southern edge of the southernmost cell. During these flight legs, the P-3 will collect tail radar data in FAST sector mode. At least one and, if possible, multiple balloon-borne EFM soundings will be collected to document the electrical structure of the southernmost cell. If within range, Cimarron will collect multiparameter data on the southernmost cell while lightning data obtained from the NLDN will be used to document the cells CG lightning characteristics.

3.4.6 **OBJECTIVE E6:** Three-dimensional mapping of MCS lightning

**PROCESS TO BE STUDIED:** Recent investigations of MCS electrical structure have indicated that charge within the stratiform precipitation region is commonly distributed into horizontally extensive layers. Concurrent observations of CG lightning in MCS stratiform regions indicate that they are predominantly positive polarity and are typically much stronger than those seen in the convective line. These observations, and additional observations of frequent and extensive IC flashes, raises many questions regarding the relationship of stratiform discharges to the observed charge structure.

**MEASUREMENT REQUIREMENTS:** Data collected in support of other objectives will be compared with three-dimensional data lightning maps, as measured by the total lightning mapper, and two-dimensional strike locations to understand the relationship of stratiform discharges to observed microphysical and electrical structures.

3.5 **References**


All forecasting and nowcasting operations for MEaPRS will be conducted from the NSSL/SPC Science Support Area (SSA). The MEaPRS forecasting and nowcasting support effort will operate 7 days a week for the full operational period of the experiment. It will be necessary for all MEaPRS personnel who will be working in the SSA in a nowcasting capacity to receive training prior to the start of the experiment. The SSA will be reserved for approximately 1 week prior to the experiment for training purposes. Proper training will take approximately two days.

In this document, a distinction is made between MEaPRS forecasting and nowcasting responsibilities. Forecasting support is defined as daily and long-term (up to 30 hours) prediction, while nowcasting support is defined as short-term (less than 3 hours) prediction of convective development and real-time support of field operations. It is anticipated that forecasting for MEaPRS will involve the participation of the NSSL/Mesoscale Application Group members and volunteer SPC forecasters, possibly as part of a probabilistic MCS forecasting experiment. Nowcasters will be drawn from participating MEaPRS scientists and students.

4.1 Nominal Daily Schedule

The following chronology provides a working guide for daily forecasting/nowcasting operations. Much of the schedule is dictated by operational constraints of the P-3 aircraft, which requires advance notice of takeoff (TO) time well in advance of specified missions (specific details of the P-3 operational constraints are addressed later in this document). The typical daily schedule, which is depicted schematically by Fig. 3, is listed below. This schedule will be adjusted for early P-3 departures.

- 08:00 - 12:00 CDT: The forecast team performs analyses to forecast the probability of MCS development over the MEaPRS observational domain for the current and following day.

- 12:00 CDT: Daily planning meeting. The forecast team briefs the PIs. The plan of the day is finalized and decisions regarding the next days mission are made. If a GO day, the P-3 takeoff (TO) time is determined and the flight crew is alerted. A decision is made on when and where to deploy the mobile laboratories.

- TO - 4 hours: Nowcast operations begin.

- TO - 2 hours: The final GO/NOGO decision is made for the P-3 mission. If GO, the P-3 crew departs for OKC.

Following the departure of the P-3 from OKC, communication via VHF radio and flight phone is established between the MEaPRS Operations Director and the P-3 chief scientist. The Remote Aircraft Tracker System (RATS) will provide P-3 location on the NSSL (Radar Algorithms and Display System) RADS display of KTLX data running in real-time in the SSA.
4.2 Forecaster Responsibilities

**FORECAST NEEDS:** The forecaster will prepare 6 and 12 hour forecasts of the probability of 1) deep convection and 2) MCSs within the MEaPRS domain, valid at 23 and 5 UTC (local midnight). The forecasts could be in the form of contour lines of equal probability overlaid directly onto a map of the geographical region of focus. The forecaster will also prepare a 30 hour outlook in the form of a map of MCS probability (valid at 23 UTC on the following afternoon). Here MCS refers only to some group or cluster of organized deep convection which may be accompanied by a region of more uniform, relatively light, non-convective precipitation. An MCS mode forecast is NOT required. The MEaPRS operational domain is bounded as follows: 1) on the west, by west Texas and eastern Colorado, 2) on the east, by eastern Oklahoma and Kansas, 3) on the south, by north Texas, 4) on the north, by central Kansas.

**FORECAST DISSEMINATION:** The forecaster will present the 6, 12 and 30 hour forecasts, along with other pertinent current and forecast weather information, at a noon-time briefing attended by the PIs and other interested scientists.

**FORECAST COMMENTS:** Most of the convection and MCS activity during May and June is anticipated to initiate either orogenically over the higher terrain of New Mexico and Colorado, or along or near boundaries over the southern and central Plains such as slow-moving or quasi-stationary fronts, old outflow boundaries from decayed convection, or drylines. Though MCSs may develop within 200 km of OKC, the initial convection and organization of that convection into an MCS often occurs near or outside the western and northern boundaries of the MEaPRS operational domain. The targetable MCSs of greatest interest are those in which some portion of the precipitation shield will track over OKC.
4.3 Nowcaster Responsibilities

**NOWCAST NEEDS:** Nowcasting the development of deep convection and MCSs will be a critical component of MEaPRS. This function will also be performed in the SSA and will begin approximately 4 hours prior to the scheduled P-3 takeoff time. Nowcasting will continue into the night in support of field operations. Ideally, nowcast support during field operations will involve participation of the Operations Director, one nowcaster, and one student assistant. In addition, the Cimarron control center will be relocated to the SSA during MEaPRS. Therefore, the Cimarron radar coordinator will also be available to assist in radar interpretation and scan coordination with the central Oklahoma WSR-88D radars (KTLX and KCRI).

**NOWCAST DISSEMINATION:** During field operations, the Operations Director will be responsible for coordinating nowcast input, position the mobile laboratories, schedule balloon-borne EFM launches, and coordinate aircraft flight patterns with the P-3 chief scientist.

**NOWCAST COMMENTS:** The primary function of the nowcast team is to monitor data and relay information about storm location, movement, and significant changes in storm structure. This function will require real-time access to many of the SPC operational data feeds. In general, the required products for nowcasting support include: Mid-west US radar composite, Twin Lakes WSR-88D reflectivity and winds, one km resolution infrared and visible satellite imagery, NLDN lightning data, profiler winds, Oklahoma mesonet data, LAPS products, and NGM forecast products. The nowcaster will work with the data manager and the NSSL/MAG and SPC liaisons to MEaPRS (Charlie Crisp and Paul Janish, respectively) to assure that SSA data are being archived during the course of the project.

4.4 Communications

As with any field experiment, good communications are important towards assuring the success of the project. As such, several redundant communications links will be established between the operations center and the chief scientists of the mobile facilities. The primary means of communication between the operations center and the P-3 aircraft will be VHF radio (122.925 MHz), flight phone, and possibly also satellite communications; the primary means of communication between the operations center and the mobile laboratories will be cell phone. It will also be possible for the mobile laboratories to directly coordinate operations with the P-3 using VHF radio.

Past experience has shown that communication systems occasionally fail in the severe weather and highly electrified environments in which MEaPRS will be taking place. In those cases, the mobile laboratory and P-3 Chief Scientists will exercise their best judgments based on their most recent communications with the Operations Director.

4.5 Decision Responsibilities

The daily decision responsibilities for field operations are depicted schematically by Fig. 4. *Due to space restrictions in the SSA, it will not be possible for all MEaPRS PIs and participants to attend the daily weather briefing.* Therefore, MEaPRS PIs will be responsible for providing input to the Operations Coordination Team (consisting of the Operations Director, nowcaster, Cimarron radar coordinator, mobile laboratory coordinator, P-3 chief scientist, and AOC representative) prior to each days briefing (see Fig. 4). At 12:00 CDT, the forecaster will then brief then Operations Coordination Team on the daily and longer range outlooks. The discussion will also include issues such as facility status reports, budget considerations, and instrument availability. Based on the 6-12 hour forecast and facility reports, the Operations Coordination Team will collectively decide whether to operate (GO/NO GO), and given a GO decision will develop an effective mission strategy. Based on the 30-hour outlook, a decision about operating on the following day would be rendered. Given a GO decision, the P-3 Chief Scientist will alert the NOAA/AOC representative of the anticipated takeoff time and initial target point for the day's mission. The Operations Director will have the authority to make the final decision on daily operations.
Figure 4: Flow chart depicting proposed MEaPRS organization and decision responsibilities.
5. Mobile Laboratory Operations

5.1. Mobile Laboratories

During MEaPRS, three mobile laboratories from the JMRF and two balloon support rental trucks (used to transport helium and supplies for the mobile laboratories) will participate in mobile ballooning operations. These three mobile laboratories and two balloon trucks will be known as NSSL1, NSSL2, NSSL3, Balloon1, and Balloon2, respectively. Though some evolution in the mobile laboratory design has occurred over the past decade, the basic structure of the mobile laboratory and its data systems, as well as a short discussion of mobile ballooning operations, is presented by Rust (1989). For most field experiments, NSSL1 will travel independently with the support of Balloon1 while NSSL2 and NSSL3 will travel together and share the support of Balloon2.

In most cases, the mobile laboratories will be deployed to locations in advance of the convective line and will serially launch EFMs (and other instrumentation when appropriate) as the system passes overhead. Specific system-relative launch locations, along with coordinated P-3 flight legs for the various field experiments, are presented in detail in section 8. Since a large number of instruments may be in the air at any given time, it is critical that the mobile laboratory chief scientists coordinate frequency allocations prior to each mission. The P-3 pilots request the following information (to be provided by the P-3 Chief Scientist in coordination with the mobile laboratories): 1) the launch location (lat/lon) and time of each balloon launch, and 2) the approximate shortest distance from the airborne balloon to the P-3 flight track.

In addition to mobile ballooning operations, when possible, mobile laboratory crews will make efforts to collect and measure hail sizes when in the vicinity of hail shafts in support of the project’s polarimetric objectives.

5.2 Mobile Ballooning Instrumentation

As stated earlier, the primary data collection responsibility of mobile laboratory crews will be to launch balloon-borne instruments. All total, five different instruments will be flown during MEaPRS. Prior to each mission, the PIs associated with each instrument will coordinate launch strategies to assure that sufficient data sets in support of each scientist’s objectives are collected during the project. The balloon-borne instruments and associated PIs are:

- Electric Field Meters: Marshall, Stolzenburg, Rust
- Q-D Instrument: Bateman, Winger
- X-ray Instrument: Beasley, Eack
- Field Change Instrument: Beasley, Eack
- Cloud Particle Replicator: Heymsfield

Given the complexity of launching balloons with several instruments in the severe weather conditions expected in MEaPRS, it will typically be necessary for a 7 person crew to be assigned to each mobile laboratory. There should be ample opportunity prior to the start of MEaPRS to train scientists to fill in at one or more of the key ballooning positions.
5.3 Balloon Launch Strategies

On any given mission, the mobile laboratories will typically be positioned to follow one of two different launch strategies. For investigations of two-dimensional MCS charge structure, the mobile laboratories will line up perpendicular to the convective line. NSSL2 will launch a pressure-temperature-humidity (PTH) sounding ahead of the convective line. Sounding data should be taken to the tropopause or until the team must prepare for the first MCS flight. NSSL1 and NSSL2 will then launch balloon-borne EFMIs into the convective updraft and downdraft, respectively (launches separated by 5-10 minutes) followed by alternating NSSL1 and NSSL2 EFM launches approximately every 1 hour. For investigations of three-dimensional MCS charge structure, the mobile laboratories will initially line up perpendicular to the convective line. NSSL2 will launch a PTH sounding ahead of the convective line. NSSL2 and NSSL1 will then launch balloon-borne EFMIs into the convective updraft and downdraft, respectively (launches separated by 5-10 minutes). After launch, NSSL1 will immediately move to a line-parallel position to that of NSSL2. NSSL1 and NSSL2 will then launch EFMIs simultaneously approximately every hour. Both of these launch strategies are schematically depicted, along with corresponding P-3 flight strategies, in section 8. On occasion, single EFM flights may be made in support of other scientific objectives. The launch of other balloon-borne electrical instrumentation (Q-D, x-ray, field change, and cloud particle replicator) from NSSL1, NSSL2 and NSSL3 will be coordinated by mobile laboratory chief scientists.

In addition to polarimetric measurements, ground-based radar operations during MEaPRS will include the collection of dual-Doppler radar data over central Oklahoma. In this section, National Weather Service (NWS) and Department of Defense (DOD) single-Doppler radar data collection within the MEaPRS experimental domain and the coordination of the central Oklahoma WSR-88D NWS radars (KTLX and KCRI) with CIM data collection are discussed.

6.1 Polarimetric Radar Coverage

In general, polarimetric radar data of sufficient quality to address the polarimetric objectives of MEaPRS will extend to a range of approximately 100 km from Cimarron. In addition to the standard radar products of reflectivity, radial winds, and spectral width, the polarimetric variables of differential reflectivity \(Z_{dr}\), differential phase shift \(\phi_{dp}\), and correlation coefficient \(\rho_{hv}(0)\) are computed in real time and archived on tape. Post-processing of the differential phase propagation also yields specific differential phase \(K_{dp}\), which is useful at interpreting rainfall rates and the orientation of aligned hydrometeors. Characteristics of the Cimarron radar are listed in Table 1.

<table>
<thead>
<tr>
<th>Table 1: Characteristics of Cimarron radar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
</tr>
<tr>
<td>Peak Power</td>
</tr>
<tr>
<td>Beam width</td>
</tr>
<tr>
<td>Maximum sidelobe level</td>
</tr>
<tr>
<td>Antenna gain</td>
</tr>
<tr>
<td>Pulse width</td>
</tr>
<tr>
<td>Receiver noise level</td>
</tr>
<tr>
<td>Matched filter bandwidth (6 dB)</td>
</tr>
<tr>
<td>System losses</td>
</tr>
<tr>
<td>Cross-polar isolation</td>
</tr>
</tbody>
</table>

6.2 Dual-Doppler Radar Coverage

The National Weather Service operates two WSR-88D radars in central Oklahoma. KTLX is an operational radar operated by the Norman, Oklahoma WSFO while KCRI is a training radar operated by the WSR-88D Operational Support Facility (OSF). The locations and heights of Cimarron, KTLX, and KCRI, respectively, are listed in Table 2.

<table>
<thead>
<tr>
<th>Table 2: Locations/heights of central Oklahoma Doppler radars</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>CIM</td>
</tr>
<tr>
<td>KTLX</td>
</tr>
<tr>
<td>KCRI</td>
</tr>
</tbody>
</table>

KTLX: The Cimarron-KTLX radar pair provides dual-Doppler coverage with a baseline of 51.1 km. The two precipitation mode Volume Coverage Patterns (VCP) typically scanned by the WSR-88D radars are listed in Table 3. During field operations, efforts will be made to request that the WSFO run VCP 11 (which has better data resolution in the upper levels) to assure good quality.
vertical velocities calculations in dual-Doppler analyses. A recorder will be installed at NSSL to record KTLX Level II data locally.

**KCRI:** The Cimarron-KCRI radar pair provides dual-Doppler coverage with a baseline of 41.4 km. Due to the shorter baseline and overlap of the dual-Doppler lobes with those provided by the Cimarron-KTLX, Cimarron-KCRI will primarily serve as a backup to KTLX. Unlike KTLX, KCRI is a training radar and therefore does not run continuously. It will therefore be the responsibility of the MEaPRS PIs to inform the Operations Director when KCRI data are required. The Operations Director will then contact an Electronics Technician at the WSR-88D hotline to start data collection. As with KTLX, VCP 11 will be requested.

<table>
<thead>
<tr>
<th>VCP</th>
<th>Time (min)</th>
<th>t (µs)</th>
<th># of elevations</th>
<th>Max elevation (deg)</th>
<th>RPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>5</td>
<td>1.57</td>
<td>14</td>
<td>19.5</td>
<td>~3</td>
</tr>
<tr>
<td>21</td>
<td>6</td>
<td>1.57</td>
<td>9</td>
<td>19.5</td>
<td>~2</td>
</tr>
</tbody>
</table>

**6.3 NWS and DOD WSR-88D Radar Sites**

Several NWS and DOD radar sites throughout the MEaPRS experiment domain will provide single-Doppler radar coverage that will be vital to many of the scientific objectives of MEaPRS. In particular, WSR-88D sites at Altus Air Force Base (KFDR) and Vance Air Force Base (KVNX) will provide coverage of western Oklahoma. Past field projects have shown that Level II data are not always archived at these sites. Therefore, during MEaPRS, Maj. Edward Ciardi of the OSF has agreed to act as a liaison between the Operations Director and DOD radar sites to assure that data are archived during field operations. Level II data from the other WSR-88D sites in the experiment domain will typically be available from the National Climatic Data Center. The locations of these WSR-88D radar sites are listed in Table 10 and located in Figure 1.

**6.4 Scanning Strategies**

**6.4.1 Twin Lakes WSR-88D (KTLX):**

The Twin Lakes WSR-88D radar will provide three kinds of information: 1) surveillance radar coverage throughout much of Oklahoma, 2) velocity data (out to a range of about 110 km) that will be combined with velocity data from the Cimarron radar to yield four-dimensional airflow fields in one or both fixed regions of analysis northeast of and southwest of the baseline between Cimarron and KTLX, and 3) velocity data (out to a range of about 110 km) that will be combined with velocity data from the P-3 tail radar to yield four-dimensional airflow fields where KTLX’s coverage overlaps that of the P-3 tail radar.

KTLX invariably performs full (360-deg azimuth) volume scans at a series of elevations. The exact volume scan used must satisfy the operational needs of the NWS. MEaPRS research goals would be best met with volume scan VCP 11, in which 14 unique elevations are scanned in a period of 5 minutes. Much less desirable is volume scan VCP 21, in which 9 unique elevations are scanned in a period of 6 minutes. The project should request that the NWS use VCP 11 (if it meets operational requirements) during MEaPRS operational periods, especially when the weather of interest is within the Cimarron-KTLX dual-Doppler analysis region or when P-3 tail radar data are within 110 km of KTLX.

Archive of Level II data will be performed.

**6.4.2 Norman WSR-88D (KCRI):**

The Norman WSR-88D radar will operate to some extent as a backup to KTLX. Because of their short baseline, KTLX and KCRI are not a practical dual-Doppler pair. For the same reason, KCRI adds only a
little geometric diversity to analyses involving the surface-based radars and the P-3 tail radar. Its contribution to multiple-radar analyses, however, is not negligible. Its inclusion should reduce errors; its inclusion may help with dealiasing other radars; its inclusion may help fill in the analysis from the P-3 tail radar when the P-3's flight path is not straight; and, most important, its inclusion may help remedy the coarse volume scanning of WSR-88D radars, especially if KTLX is performing volume scan VCP 21 instead of VCP 11.

Archive of Level II data will be performed.

6.4.3 Cimarron:

The Cimarron radar will provide three kinds of information: 1) polarimetric data that provide information on the size, shape, and composition of the hydrometeors, 2) velocity data (out to a range of about 110 km) that will be combined with velocity data from KTLX and KCRI to yield four-dimensional airflow fields in one or both fixed regions of analysis northeast of and southwest of the baseline between Cimarron and KTLX, and 3) velocity data (out to a range of about 110 km) that will be combined with velocity data from the P-3 tail radar to yield four-dimensional airflow fields where Cimarron’s coverage overlaps that of the P-3 tail radar. Cimarron will be operated remotely from NSSL in two modes.

**MODE 1:** When the weather of interest is not within one of the fixed analysis regions northeast of and southwest of the baseline between Cimarron and KTLX, and when Cimarron will collect polarimetric and conventional data in simple sector scans at elevations of 0.2, 1.2, 2.2, 3.2, 4.2, and 5.2 deg. 128 samples per ray will be collected. The azimuthal rotation rate will be 6 deg s⁻¹. When the P-3 is not flying, the sectors should encompass the weather system. When the P-3 is flying, the sectors should concentrate on the region of the system in the vicinity of its flight path and within the coverage of the tail radar. Data will be most useful within a range of 110 km. Occasionally, polarimetric volume scans, as described below, will be performed to investigate regions of negative Kdp.

**MODE 2:** When the weather of interest is within one of the fixed analysis regions northeast of and southwest of the baseline between Cimarron and KTLX, volume scans will be performed to collect data to enable four-dimensional velocity fields to be deduced. Polarimetric data will also be collected during these scans. The azimuthal rotation rate and the elevations scanned will be determined by an optimization algorithm that takes into consideration the echo extent and depth. (The algorithm controls the azimuthal and elevational resolution at the maximum useful slant range in echo.) Scans typically will consist of between 20 and 30 elevations. 64 samples per ray will be collected. The volume scan period will be 5 minutes to match that of volume scan VCP 11 of the WSR-88D radars. There is no advantage to coordinating scan start times with the WSR-88D radars. When the P-3 is flying, the scanned sector will be broadened, in necessary, to include the vicinity of its flight path and the coverage of the tail radar.

The velocity volume scans (VS) will be interleaved with polarimetric volume scans (PS) according to the following scheme:

| VS (5 min) | VS (5 min) | PS (2-5 min) | VS (5 min) | VS (5 min) | PS (2-5 min) | etc. |

The PSs will consist of a sequence of sweeps in elevation at various azimuths. The elevation range will be from 0.2 to 20 deg. The azimuthal step will be 1 to 2 deg. The elevational rotation rate will be 2 deg s⁻¹. 128 samples per ray will be collected. The polarimetric volume scans will consist of from 12 to 30
sweeps. Which azimuthal sectors to scan in a PS will be determined during the preceding VSs. Selection will be based on precipitation pattern (e.g., strong stratiform rain areas), proximity of aircraft, and interesting polarimetric data signatures (e.g., negative $K_{dp}$ in snow crystals indicating possible vertical alignment of crystals in electric field, high $K_{dp}$, $Z_{dr}$ in rain immediately below intense bright band). Since regions of negative $K_{dp}$ may be transitory, a VS may sometimes be aborted so that the negative $K_{dp}$ region can be examined with a PS.

If possible, Cimarron will be operated with the largest pulse repetition frequency (PRF), 1302 s$^{-1}$, because relatively fast antenna rotation rates are required to cover the large solid angles of mesoscale weather systems. However, severe contamination by second-trip echoes may necessitate the use of lower PRFs. The rather low maximum antenna rotation rate of Cimarron compatible with the collection of polarimetric measurements rules out performing full (360-deg azimuth) volume scans. It is desirable that one of the two fixed analysis regions be selected for observation for long durations. If both analysis regions are designated as the weather of interest, then each will be scanned separately during the two consecutive PS in the interleaved scan scheme.
7. Aircraft Operations

One NOAA P-3 aircraft has been committed to MEaPRS for 50 research flight hours. The two primary responsibilities of the P-3 will be to gather pseudo-dual-Doppler and in-situ cloud microphysical data in support of MEaPRS electrification and polarimetric radar objectives.

7.1 Operational Constraints

AOC has developed several rules regarding P-3 flight missions to ensure safe operations yet allow maximum flexibility to adjust to changing weather and multiple scientific objectives. These constraints are summarized in Table 4.

<table>
<thead>
<tr>
<th>Constraints</th>
<th>Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anticipated next-day takeoff time</td>
<td>Must be specified at least 24 hours in advance</td>
</tr>
<tr>
<td>Crew duty day</td>
<td>16 hours</td>
</tr>
<tr>
<td>Minimum crew rest between duty days</td>
<td>15 hours</td>
</tr>
<tr>
<td>Maximum consecutive mission days</td>
<td>6</td>
</tr>
<tr>
<td>Minimum pre-flight preparation time</td>
<td>3 hours</td>
</tr>
</tbody>
</table>

The anticipated next-day takeoff time specifies the start of the crew duty day. The mission must be completed within 16 hours of this time including any delays in takeoff. A “hard-down” day must be given after the sixth consecutive mission day, or following 3 consecutive late night missions. A mission day is defined as an alert day whether or not the aircraft actually flies a mission. A down day is declared at the weather briefing for the next day. The P-3 scientific personnel will also adhere to the crew duty day and crew rest operational constraints.

7.2 Scientific Flight Crew Positions

The operation of the specialized scientific equipment on the P-3 (lower fuselage and tail radar, cloud physics system) is normally performed by the scientific crew. Personnel from AOC monitor the performance and recording of the main data system (in-situ flight level data). The required scientific positions on the P-3 are as detailed in Table 5.

<table>
<thead>
<tr>
<th>Position</th>
<th>Number of People</th>
<th>Duties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chief Scientist</td>
<td>1</td>
<td>Plan flight tracks in coordination with Flight Director</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Supervise data collection</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coordinate with Operations Center &amp; Mobile Laboratories</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Monitor system performance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maintain tape and event logs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Change tapes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Help interpret radar displays</td>
</tr>
<tr>
<td>Doppler Radar</td>
<td>1</td>
<td>Monitor system performance (1 cloud physics/ 1Q-probe)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maintain tape and event logs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Change tapes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Help interpret PMS displays</td>
</tr>
<tr>
<td>Cloud Physics</td>
<td>2</td>
<td>Help interpret meteorology and assist Chief Scientist</td>
</tr>
<tr>
<td></td>
<td>(optional)</td>
<td>Maintain scientific logs</td>
</tr>
<tr>
<td>Observers</td>
<td>2 (optional)</td>
<td></td>
</tr>
</tbody>
</table>
7.3 Instrumentation

There are three basic data systems on the P-3. These include the radar data system, the cloud physics data system, and the main data system.

7.3.1 Radar Data System:

The P-3 aircraft is fitted with two research radars onboard. They are a 5 cm lower fuselage radar (LF) that measures returned power only and a 3 cm tail mounted Doppler radar (TA). The 5 cm LF is mounted below the lower surface of the aircraft and scans in a PPI mode. The radar is capable of performing complete 360° sweeps or sector scans of less than 360° and operates nominally at 2 rpm. The radar, operating at 200 PRF, has an unambiguous range of ~750 km, and can archive a maximum of 512 gates (or bins) of information. The maximum range that can be archived is simply the product of the 512 gates times the pulse length. The pulse length is variable between 125 m and 750 m in 125 m steps. Both the pulse length as well as the sector size are operator selectable. Some of the LF characteristics are given in the Table 6.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scanning method</td>
<td>PPI</td>
</tr>
<tr>
<td>Wavelength</td>
<td>5.59 cm (C-band)</td>
</tr>
<tr>
<td>Beamwidth</td>
<td></td>
</tr>
<tr>
<td>Horizontal</td>
<td>1.1°</td>
</tr>
<tr>
<td>Vertical</td>
<td>4.1°</td>
</tr>
<tr>
<td>Gain</td>
<td>37.5 dB</td>
</tr>
<tr>
<td>Sidelobe (dB down from main lobe)</td>
<td>-23 dB</td>
</tr>
<tr>
<td>Scan rate</td>
<td>2 RPM</td>
</tr>
<tr>
<td>Tilt elevation range</td>
<td>±10°</td>
</tr>
<tr>
<td>Range resolution</td>
<td>750 m (maximum; half pulse length)</td>
</tr>
<tr>
<td>Pulse Repetition Rate (PRF)</td>
<td>200 s⁻¹</td>
</tr>
<tr>
<td>Unambiguous range</td>
<td>750 km</td>
</tr>
<tr>
<td>Maximum range (archived)</td>
<td>384 km</td>
</tr>
</tbody>
</table>

The TA is mounted on the tail of the aircraft and scans in RHI mode which, due to forward aircraft motion, is better characterized as a helical pattern. The “French antenna” is being used for MEaPRS. The French antenna is a dual plate antenna with one plate directing the radar beams ~20° aft of the normal vector to the aircraft heading and the other directing the beams ~20° forward of the normal vector. As each sweep is completed, the power is alternately directed to the other antenna plate, and hence, alternating forward and aft sweeps are accomplished. The French antenna can rotate at a maximum of 10 rpm and can provide either 360° continuous sweeps or 180° sector sweeps to either side of the aircraft. Some of the characteristics of the TA are given in the Table 7.
Table 7: Characteristics of the NOAA P-3 Airborne Doppler Radar

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scanning method</td>
<td>RHI</td>
</tr>
<tr>
<td>Wavelength</td>
<td>3.22 cm (X-band)</td>
</tr>
<tr>
<td>Beamwidth</td>
<td></td>
</tr>
<tr>
<td>CRPE (French) flat-plate antenna</td>
<td></td>
</tr>
<tr>
<td>Horizontal</td>
<td>2.07°/2.04° (aft/fore beams)</td>
</tr>
<tr>
<td>Vertical</td>
<td>2.10° (aft and fore beams)</td>
</tr>
<tr>
<td>Polarization (along sweep axis)</td>
<td></td>
</tr>
<tr>
<td>French antenna</td>
<td>Linear horizontal</td>
</tr>
<tr>
<td>Sidelobes (dB down from main lobe)</td>
<td></td>
</tr>
<tr>
<td>French antenna</td>
<td></td>
</tr>
<tr>
<td>Horizontal</td>
<td>Aft beam: -57.6 dB; Fore beam: -55.6 dB</td>
</tr>
<tr>
<td>Vertical</td>
<td>Aft beam: -41.5 dB; Fore beam: -41.8 dB</td>
</tr>
<tr>
<td>Gain</td>
<td></td>
</tr>
<tr>
<td>French antenna</td>
<td>Aft beams: 34.85 dB; Fore beams: 35.90 dB</td>
</tr>
<tr>
<td>Scan rate</td>
<td>0-10 RPM</td>
</tr>
<tr>
<td>Fore/Aft tilt</td>
<td></td>
</tr>
<tr>
<td>French antenna</td>
<td></td>
</tr>
<tr>
<td>Pulse Repetition Frequency (PRF)</td>
<td>1600 s⁻¹ (maximum)</td>
</tr>
<tr>
<td>Pulses averaged per radial sample</td>
<td>32</td>
</tr>
<tr>
<td>Unambiguous Nyquist interval</td>
<td>±12.88 ms⁻¹ (1600 s⁻¹ PRF)</td>
</tr>
<tr>
<td>Unambiguous range</td>
<td>93.7 km</td>
</tr>
<tr>
<td>Range resolution (0.5 µs pulse duration)</td>
<td>75 m (half pulse length)</td>
</tr>
</tbody>
</table>

7.3.2 Cloud Physics Data System:

The P-3 aircraft is fitted with two optical array probes with size resolutions of 150 µm (2DG-P) and 30 µm (2DG-C), respectively. These probes are typically referred to as “grey probes” as, in addition to having a size resolution that is improved over earlier versions, they are also capable of discriminating four different shades of optical intensity. The characteristics of the 2DG-P and 2DG-C probes are given in Table 8.

Table 8: Characteristics of the NOAA P-3 Optical Array Probes

<table>
<thead>
<tr>
<th>Parameter</th>
<th>2DG-P</th>
<th>2DG-C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size range</td>
<td>9.6 mm</td>
<td>1.92 mm</td>
</tr>
<tr>
<td>Resolution</td>
<td>150 microns</td>
<td>30 microns</td>
</tr>
<tr>
<td>Ice/water discrimination</td>
<td>No</td>
<td>Depolarizer</td>
</tr>
</tbody>
</table>

Other cloud microphysics instrumentation to be flown on the P-3 during MEaPRS include: a 15-channel Forward Scattering Spectrometer Probe (FSSP), and a Johnson-Williams (JW) cloud liquid water probe. Four King Air cloud liquid water probes have also been made available to MEaPRS. Cloud particle charge measurements will be made by a Desert Research Institute/University of Manchester (DRI/UMIST) Q-probe, which has a sensitivity of approximately ±1 pC.

7.3.3 Main Data System:

Characteristics of the main data system sensors are given in Table 9. The sensors that are serviced by the main data system are sampled at a rate of 40 Hz, and then are averaged to yield 1 sample per second. Derived parameters (such as wind) are calculated in post-processing once calibrations and biases are determined and removed.
Table 9: Characteristics of the NOAA P-3 main data system sensors

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Instrument</th>
<th>Manufacturer</th>
<th>Accuracy</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positioning</td>
<td>Inertial Navigation Equipment (INE)</td>
<td>Northrop/Delco</td>
<td>1.5 km (after post-processing)</td>
<td>8.3x10^-8°</td>
</tr>
<tr>
<td>Temperature</td>
<td>Platinum resistance</td>
<td>Rosemount</td>
<td>0.5° C</td>
<td>0.03° C</td>
</tr>
<tr>
<td>Dewpoint</td>
<td>Cooled Mirror</td>
<td>General Eastern</td>
<td>0.5° C</td>
<td>0.03° C</td>
</tr>
<tr>
<td>Static pressure</td>
<td>Transducer</td>
<td>Garrett</td>
<td>1.0 mb</td>
<td>0.1 mb</td>
</tr>
<tr>
<td>Dynamic pressure</td>
<td>Transducer</td>
<td>Rosemount</td>
<td>0.5 mb</td>
<td>0.1 mb</td>
</tr>
<tr>
<td>Attack pressure</td>
<td>Transducer</td>
<td>Rosemount</td>
<td>1.0%</td>
<td>0.1 mb</td>
</tr>
<tr>
<td>Sideslip pressure</td>
<td>Transducer</td>
<td>Rosemount</td>
<td>1.0%</td>
<td>0.1 mb</td>
</tr>
<tr>
<td>Absolute altitude</td>
<td>Radar Altimeter</td>
<td>Stewart-Warner</td>
<td>0.01%</td>
<td>1 m</td>
</tr>
<tr>
<td>Cloud water</td>
<td>Hot Wire</td>
<td>Johnson-Williams</td>
<td>0.2%</td>
<td>0.1 g m^-3</td>
</tr>
<tr>
<td>In-cloud temp.</td>
<td>CO2 radiometer (14 µm)</td>
<td>Barnes/AOC</td>
<td>1.0° C</td>
<td>0.1° C</td>
</tr>
<tr>
<td>Ground speed</td>
<td>INE accelerometers</td>
<td>Northrop/Delco</td>
<td>0.5 m s^-1</td>
<td>0.06 m s^-1</td>
</tr>
<tr>
<td>Track angle</td>
<td>INE accelerometers</td>
<td>Northrop/Delco</td>
<td>0.2°</td>
<td>0.005°</td>
</tr>
<tr>
<td>Heading angle</td>
<td>INE accelerometers</td>
<td>Northrop/Delco</td>
<td>0.1°</td>
<td>0.005°</td>
</tr>
<tr>
<td>Pitch angle</td>
<td>INE accelerometers</td>
<td>Northrop/Delco</td>
<td>0.06°</td>
<td>0.005°</td>
</tr>
<tr>
<td>Roll angle</td>
<td>INE accelerometers</td>
<td>Northrop/Delco</td>
<td>0.06°</td>
<td>0.005°</td>
</tr>
</tbody>
</table>
8. Field Experiments

8.1 Overview of Field Experiments

Specific field experiment designs are presented in this section. One of the advantages of using the P-3 aircraft to investigate weather phenomena is the ability to adjust flight patterns to fit the pattern of storms and precipitation. The variability of MCS morphology and evolution makes precise pre-planning of specific flight patterns difficult, and what is in the following section are only generic flight patterns showing what typically could be done to address each of the scientific objectives. In addition, flight safety requirements specify that the P-3 not penetrate any convective cell where the possibility exists of damage due to turbulence, strong updrafts and downdrafts, and/or damage from hail, graupel, or icing. No penetration of convective features (as evidenced on the nose radar display) will be attempted. Flight paths through extensive stratiform precipitation will be a priority for investigation.

As noted earlier, to facilitate the presentation of experiment designs to address all scientific objectives, the project domain has essentially been divided into three regions. These three regions are specified as being: I) outside of Cimarron range, II) within 100 km of Cimarron but outside of dual-Doppler coverage, and III) within dual-Doppler coverage. In region I, which is out of the ground-based radar coverage required to accomplish much of the project’s electrical and polarimetric goals, efforts will be made to address the scientific goals that are best described as MCS dynamics. In region II, which is within 100 km of Cimarron but outside of dual-Doppler coverage, more emphasis will be placed on the project’s microphysical, polarimetric, and electrical objectives. Finally, in region III, where quality ground-based dual-Doppler radar coverage exists, the P-3 will be given more flexibility in its flight patterns, but emphasis will still be placed on collecting high-quality comprehensive data sets that address the electrical and polarimetric needs of MEaPRS. As such, the experiments presented here are not necessarily presented in order of their importance to the overall project objectives, but rather the order that they will likely be addressed in a typical P-3 mission.

8.2 Summary of Regions

Option I: The flight patterns for Region I generally attempt to document either 1) the convective line structure, or 2) mesoscale circulations associated with line-end vortices. The P-3 will typically be acting alone in this region and is therefore free to change flight strategies and tail radar scanning modes to maximize the coverage or minimize errors.

Option II: When in Region II, the flight patterns generally attempt to document either 1) the kinematic structure in the vicinity of EFM launches, or 2) the microphysical structure in support of polarimetric objectives. For P-3 data collection in support of electrical objectives, the mobile laboratories will typically line up perpendicular to the convective line (2-D documentation of electrical structure) or spaced apart along the line (3-D documentation of electrical structure).

Option III: When in Region III, data collection will take place within one of the dual-Doppler lobes. The strict linear flight patterns needed in Region II will therefore be relaxed and the P-3 will be free to perform spiral ascents/descents to obtain microphysical profiles over the mobile laboratories. The mobile laboratory positioning in Region III will typically be similar to those discussed previously for Region II (i.e., 2-D and 3-D documentation of electrical structure).

It is assumed that any flight patterns within 100 km of Cimarron will be coordinated with the mobile laboratories. Should mobile laboratory coordination not be possible and the system is within 100 km of Cimarron, then alternative flight strategies will be employed to make microphysical and pseudo-dual-Doppler measurements.
8.3 Region I Field Experiments

**Option Ia:**

**Outside CIM 100 km range**

*Document convective line structure and fluxes*

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*Figure 5:* Schematic of horizontal MCS cross-sections for experiment Option Ia.

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**Option Ia:**

**Goal:** Document convective line structure and fluxes

**Aircraft:** The P-3 will perform a descent sounding (from ferry level) approximately 50 km ahead of the convective line. The P-3 will then conduct a series of 50-80 km long legs 10-20 km ahead of the line and an altitude of 3 kft. Tail Doppler radar data will be collected in FAST-sector mode during the flight legs. If possible, this pattern will be repeated for several hours.

**Mobile Labs:** A mobile laboratory crew will launch soundings (approximately 1 per hour) at a location 40 km in front of the convective line.

**Cimarron:** The Cimarron radar is not required for this experiment.
Option Ib:
Outside CIM 100 km range

Document mesoscale circulations

~30 min (120 nm) legs
P-3 mid level (~10,000 AGL)
TA radar 360° scan

Figure 6: Schematic of horizontal MCS cross-sections for experiment Option Ib.

Option Ib:

Goal: Document mesoscale circulations

Aircraft: The P-3 will conduct a series of 30 minute flight legs at an altitude of 10 kft that encompass the center of any line-end vortices and/or circulation features. Tail Doppler radar data will be collected in FAST-continuous mode during the flight legs.

Mobile Labs: The mobile laboratories are not required for this experiment.

Cimarron: The Cimarron radar is not required for this experiment.

Notes: It is possible that this flight pattern might also be performed in Region II. In that case, balloon launches and Cimarron data collection may be added to this experiment.
**Option Ic:**

**Outside CIM 100 km range**

*Document convective fluxes and microphysics rearward*

---

**P-3 various altitudes**
- TA radar 360° scan
- 10 min (~40 nm) legs
- 5-10 nm behind the convective line
- Flight levels ~ +5°C, 0°C, -5°C, -10°C, -15°C, -20°C

---

**Figure 7**: Schematic of (a) horizontal and (b) vertical MCS cross-sections for experiment Option Ic. Dots in (b) depict system-relative location at which each flight leg intersects the cross-section.

---

**Option Ic:**

**Goal**: Document convective fluxes and microphysics rearward

**Aircraft**: The P-3 will conduct a series of six 10 minute flight legs at a location 10-20 km behind the convective line and altitudes corresponding to the temperature levels of +5, 0, -5, -10, -15, and -20°C, respectively. Tail Doppler radar data will be collected in FAST-continuous mode during the flight legs. If possible, this pattern will be repeated 1 hour later to document the evolution of microphysical fluxes with time.
Mobile Labs: The mobile laboratories are not required for this experiment.

Cimarron: The Cimarron radar is not required for this experiment.

Notes: Due to the nature of the P-3 data collection (i.e., microphysical and particle charge data at locations immediately behind the convective line), efforts should be made to coordinate at least 1 transition zone EFM flight with this flight pattern.
8.4 Region II Field Experiments

**Option IIa:**

**Inside CIM 100 km range, Outside dual-Doppler range**

Document mesoscale wind fields, limited microphysical sampling, 2-D EFM coverage

---

**Figure 8:** Schematic of (a) horizontal and (b) vertical MCS cross-sections for experiment Option IIa. Dots in (b) depict system-relative location at which each flight leg intersects the cross-section.

**Option IIa:**

**Goal:** Document mesoscale wind fields, limited microphysical sampling, 2-D EFM coverage

**Aircraft:** The P-3 will conduct a series of 15 minute flight legs, at various altitudes, centered on the location of one of the mobile laboratories. Tail Doppler radar data will be collected in FAST-continuous mode during the flight legs. A two minute “purl” pattern will be conducted near the center of each flight leg to document the mesoscale vertical motion structure and hydrometeor fallspeed profile.
Mobile Labs: The mobile laboratories will line up perpendicular to the convective line to document the MCS’s 2-D electrical structure. NSSL2 will launch a PTH sounding ahead of the convective line. NSSL1 and NSSL2 will then launch balloon-borne EFMs into the convective updraft and downdraft, respectively (launches separated by 5-10 minutes) followed by alternating NSSL1 and NSSL2 EFM launches approximately every 1 hour.

Cimarron: During the balloon-borne EFM launches, Cimarron will collect data in PPI mode. Since data the MCS kinematic structure in Region II is well documented by P-3 pseudo-dual-Doppler, Cimarron data collection will focus on high temporal resolution low elevation scans with which to compare aircraft microphysical profiles.

Notes: The launch of other balloon-borne electrical instrumentation (Q-D, x-ray, field change, and cloud particle replicator) from NSSL1, NSSL2 and NSSL3 will be coordinated by mobile laboratory chief scientists. Cimarron may conduct occasional RHI scans when regions of aligned ice crystals are observed.
Option IIb:

Inside CIM 100 km range, Outside dual-Doppler range

Document mesoscale wind fields, limited microphysical sampling, 3-D EFM coverage

P-3 flies various altitudes, ~60 nm leg length (15 minutes flight time), immediately behind the convective line

PURL pattern (2-min turn)

Time/space converted mobile lab positions

MCLASS or dropsonde
If practical

MCLASS Only

Figure 9: Schematic of (a) horizontal and (b) vertical MCS cross-sections for experiment Option IIb. Dots in (b) depict system-relative location at which each flight leg intersects the cross-section.

Option IIb:

Goal: Document mesoscale wind fields, limited microphysical sampling, 3-D EFM coverage

Aircraft: The P-3 will conduct a series of 15 minute flight legs, at various altitudes, centered on the location of one of the mobile laboratories. Tail Doppler radar data will be collected in FAST-continuous mode during the flight legs. A two minute “purl” pattern will be conducted near the center of each flight leg to document the mesoscale vertical motion structure and hydrometeor fallspeed profile.
Mobile Labs: The mobile laboratories will initially line up perpendicular to the convective line. NSSL2 will launch a PTH sounding ahead of the convective line. NSSL2 and NSSL1 will then launch balloon-borne EFMs into the convective updraft and downdraft, respectively (launches separated by 5-10 minutes). After launch, NSSL1 will immediately move to a line-parallel position to that of NSSL2. NSSL1 and NSSL2 will then launch EFMs simultaneously approximately every hour.

Cimarron: During the balloon-borne EFM launches, Cimarron will collect data in PPI mode. Since data the MCS kinematic structure in Region II is well documented by P-3 pseudo-dual-Doppler, Cimarron data collection will focus on high temporal resolution low elevation scans with which to compare aircraft microphysical profiles.

Notes: The launch of other balloon-borne electrical instrumentation (Q-D, x-ray, field change, and cloud particle replicator) from NSSL1, NSSL2 and NSSL3 will be coordinated by mobile laboratory chief scientists. Cimarron may conduct occasional RHI scans when regions of aligned ice crystals are observed.
**Option IIc:**

Inside CIM 100 km range, Outside dual-Doppler range  
*Document mesoscale wind fields, microphysical sampling*

**Goals:** Document spatial distribution of raindrop (Option 1) and ice (Option 2) hydrometeor characteristics within the stratiform region of the squall line system from front to rear of MCS. Airborne Doppler scans in the FAST mode using continuous 360° scans.

Extend dual-Doppler radar coverage rearward to provide better coverage of transition zone.

*Height:* 5,000 ft, 10,000 ft (Option 1) or 18,000 ft, 23,000 ft (Option 2)

**Figure 10:** Schematic of (a) horizontal and (b) vertical MCS cross-sections for experiment Option IIc.

**Option IIc:**

**Goal:** Document mesoscale wind fields, microphysical sampling

**Aircraft:** The P-3 will conduct a series of line-normal flight legs at various altitudes to document spatial distributions of raindrop (Option 1) and ice (Option 2) hydrometeor characteristics in the stratiform region. These flight legs will be flown at 5 and 10 kft (Option 1) and 18 and 23 kft (Option 2), respectively. Tail Doppler radar data will be collected in FAST-continuous mode during the flight legs. A two minute “purl” pattern will be conducted near the center of each flight leg to document the mesoscale vertical motion structure and hydrometeor fallspeed profile.
Mobile Labs: The mobile labs are not required for this experiment.

Cimarron: Cimarron will collect data in PPI mode when the P-3 is flying line-normal legs that are not along a Cimarron radial and RHI mode when the P-3 is flying along a Cimarron radial. Specific Cimarron scanning strategies are presented in Section 6.

Notes: These flight patterns may occasionally be coordinated with balloon-borne EFM launches.
8.5 Region III Field Experiments

Option IIIa:
Inside dual-Doppler range
Document mesoscale wind fields, microphysical profiles, 2-D EFM coverage

Procedure: P-3 flies from A to B then to the line AA-BB (Point 1) at 8 k ft. At Point 1 perform spiral ascent to 23 k ft. Fly from Point 1 to A then B, then return to Point 1 at 23 k ft. At point 1 perform spiral descent to 8 k ft, then fly sequence 1-A-B-1 at 8 k ft. Repeat sequence as necessary.

Figure 11: Schematic of (a) horizontal and (b) vertical MCS cross-sections for experiment Option IIIa. Vertical lines in (b) depict system-relative location at which spiral ascents/descents intersect the cross-section.

Option IIIa:

Goal: Document mesoscale wind fields, microphysical profiles, 2-D EFM coverage

Aircraft: The P-3 will conduct a series of 15 minute flight legs, at various altitudes, centered on the location of one of the mobile laboratories. The P-3 flies from A to B, then to point 1 at 8 k ft and performs a spiral ascent to 23 k ft. The P-3 then flies to A, then B, and then back to point 1 at 23 k ft and performs a spiral descent to 8 k ft. This pattern is repeated throughout EFM data collection. Tail Doppler
radar data will be collected in FAST-continuous mode during the flight legs. Spiral ascents/descents will be conducted at approximately 1000 ft min\(^{-1}\).

**Mobile Labs:** The mobile laboratories will line up perpendicular to the convective line to document the MCS’s 2-D electrical structure. NSSL2 will launch a PTH sounding ahead of the convective line. NSSL1 and NSSL2 will then launch balloon-borne EFMs into the convective updraft and downdraft, respectively (launches separated by 5-10 minutes) followed by alternating NSSL1 and NSSL2 EFM launches approximately every 30 minutes.

**Cimarron:** During the balloon-borne EFM launches, Cimarron will collect data in PPI mode. Unlike in Region II, Cimarron data in Region I will be collected to high elevation angles in order to obtain quality upper-level wind data in the Cimarron-KTLX dual-Doppler lobes. Specific Cimarron scanning strategies are presented in Section 6.

**Notes:** The launch of other balloon-borne electrical instrumentation (Q-D, x-ray, field change, and cloud particle replicator) from NSSL1, NSSL2 and NSSL3 will be coordinated by mobile laboratory chief scientists. Cimarron may conduct occasional RHI scans when regions of aligned ice crystals are observed.
Option IIIb:

Inside dual-Doppler range

Document mesoscale wind fields, microphysical profiles, 3-D EFM coverage

Procedure: P-3 flies from A to B, then back to the approximate location of NSSL1 (Point 1) at 8 k ft. Spiral ascent to 23 k ft remaining over Point 1, then fly back to point B at 23 k ft. Fly from B to A, then to the approximate NSSL2 position (Point 2) at 23 k ft. At Point 2, perform spiral descent to 8 k ft. Fly from Point 2 to A, then A to B at 8 k ft. Repeat as necessary.

Figure 12: Schematic of (a) horizontal and (b) vertical MCS cross-sections for experiment Option IIIb. Vertical lines in (b) depict system-relative location at which spiral ascents/descents intersect the cross-section.

Option IIIb:

Goal: Document mesoscale wind fields, microphysical profiles, 3-D EFM coverage

Aircraft: The P-3 will conduct a series of 15 minute flight legs, at various altitudes, centered on the location of one of the mobile laboratories. The P-3 flies from A to B, then to point 1 at 8 k ft and performs a spiral ascent to 23 k ft. The P-3 then flies to A, then B, and then back to point 1 at 23 k ft and performs a spiral descent to 8 k ft. This pattern is repeated throughout EFM data collection. Tail Doppler
radar data will be collected in FAST-continuous mode during the flight legs. Spiral ascents/descents will be conducted at approximately 1000 ft min$^{-1}$.

**Mobile Labs:** The mobile laboratories will initially line up perpendicular to the convective line. NSSL2 will launch a PTH sounding ahead of the convective line. NSSL2 and NSSL1 will then launch balloon-borne EFMs into the convective updraft and downdraft, respectively (launches separated by 5-10 minutes). After launch, NSSL1 will immediately move to a line-parallel position to that of NSSL2. NSSL1 and NSSL2 will then launch EFMs simultaneously approximately every hour.

**Cimarron:** During the balloon-borne EFM launches, Cimarron will collect data in PPI mode. Unlike in Region II, Cimarron data in Region I will be collected to high elevation angles in order to obtain quality upper-level wind data in the Cimarron-KTLX dual-Doppler lobes. Specific Cimarron scanning strategies are presented in Section 6.

**Notes:** The launch of other balloon-borne electrical instrumentation (Q-D, x-ray, field change, and cloud particle replicator) from NSSL1, NSSL2 and NSSL3 will be coordinated by mobile laboratory chief scientists. Cimarron may conduct occasional RHI scans when regions of aligned ice crystals are observed.
9. Data Management

9.1. Operational and Research Networks

WSR-88D Radar:

The NWS WSR-88D (10-cm Doppler) radar provides two types of archives - base data and products. Base data (Archive Level II) consists of data that have been preprocessed (clutter suppressed, point target filtered, V and W moments range unfolded and return power converted to dBZ and occurs at the Radar Data Acquisition (RDA) component located at the radar tower. Level II base reflectivity data are archived at 1-km resolution out to 460 km; base velocity and spectrum width data are archived at 0.25-km resolution out to 230 km. The archive medium for Level II data is Exabyte 8-mm cartridge tape. These data are archived at NCDC and can be obtained via off-line order entry on the On-line Access and Service Information System (OASIS). NCDC typically requires a nominal fee for duplication and dissemination of archived data via magnetic tape (8 mm). The NCDC system is accessible through the NSSL CODIAC.

Composites:

Regional digitized radar reflectivity composites over the U.S. are available from a commercial vendor (WSI Corp.) at the UCAR Joint Office for Science Support (JOSS). 15-minute composite files, in McIDAS AREA file format, will be archived for a fixed sector covering the MEaPRS domain. A catalog of browse radar composites Gif images will be also available.

Single Site:

Gif products for the lowest 2 scans from individual radar sites can be archived for various WSR-88D radars in the MEaPRS domain. Arrangements must be made in anticipation of capturing sites of interest to researchers.

Table 10: NWS WSR-88D Radar Sites

<table>
<thead>
<tr>
<th>ID</th>
<th>Site</th>
<th>Latitude</th>
<th>Longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>KTLX</td>
<td>Twin Lakes, OK</td>
<td>35.33</td>
<td>-97.28</td>
</tr>
<tr>
<td>KFDR</td>
<td>Frederick, OK</td>
<td>34.36</td>
<td>-98.98</td>
</tr>
<tr>
<td>KDDC</td>
<td>Dodge City, KS</td>
<td>37.76</td>
<td>-99.97</td>
</tr>
<tr>
<td>KICT</td>
<td>Wichita, KS</td>
<td>37.65</td>
<td>-97.44</td>
</tr>
<tr>
<td>KGLD</td>
<td>Goodland, KS</td>
<td>39.37</td>
<td>-101.71</td>
</tr>
<tr>
<td>KAMA</td>
<td>Amarillo, TX</td>
<td>35.24</td>
<td>-101.71</td>
</tr>
<tr>
<td>KLZI</td>
<td>Little Rock, AR</td>
<td>34.84</td>
<td>-92.26</td>
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<tr>
<td>KINX</td>
<td>Tulsa, OK</td>
<td>36.18</td>
<td>-95.56</td>
</tr>
<tr>
<td>KTOP</td>
<td>Topeka, KS</td>
<td>39.00</td>
<td>-96.23</td>
</tr>
<tr>
<td>KDXY</td>
<td>Dyess AFB, Abilene,TX</td>
<td>32.54</td>
<td>-99.25</td>
</tr>
<tr>
<td>KVNX</td>
<td>Vance AFB, Enid, OK</td>
<td>36.74</td>
<td>-97.28</td>
</tr>
<tr>
<td>KFWS</td>
<td>Dallas, TX</td>
<td>32.57</td>
<td>-97.30</td>
</tr>
<tr>
<td>KLBB</td>
<td>Lubbock, TX</td>
<td>33.65</td>
<td>-101.81</td>
</tr>
</tbody>
</table>

Sounding Sites:

National Weather Service standard soundings will be taken during MEaPRS from the existing NWS network every 12 hours (00 and 12 UTC). The radiosondes will be radio-directionally tracked (GMD) with winds measured at one minute interval. Thermodynamic data (temperature, pressure and relative
humidity using a carbon hygristor) are sampled about once per second and averaged values from the MicroART processor are stored every 6 seconds. NCDC archives the 6-sec, high resolution data; JOSS routinely quality-controls and reformats (calculates winds) from these data. The NWS soundings will be available after the field phase via CODIAC.

Table 11: NWS Sounding Sites

<table>
<thead>
<tr>
<th>WMO</th>
<th>ID</th>
<th>Site</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Elev (m)</th>
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<tr>
<td>72365</td>
<td>ABQ</td>
<td>Albuquerque, NM</td>
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<td>-106.60</td>
<td>1613</td>
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<tr>
<td>72363</td>
<td>AMA</td>
<td>Amarillo, TX</td>
<td>35.23</td>
<td>-101.70</td>
<td>1099</td>
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<tr>
<td>72451</td>
<td>DDC</td>
<td>Dodge City, KS</td>
<td>37.77</td>
<td>-99.97</td>
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<td>72469</td>
<td>DEN</td>
<td>Denver, CO</td>
<td>39.75</td>
<td>-104.87</td>
<td>1625</td>
</tr>
<tr>
<td>72270</td>
<td>ELP</td>
<td>El Paso, TX</td>
<td>31.80</td>
<td>-106.40</td>
<td>1194</td>
</tr>
<tr>
<td>72340</td>
<td>LZR</td>
<td>Little Rock, AR</td>
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<td>-92.23</td>
<td>78</td>
</tr>
<tr>
<td>72265</td>
<td>MAF</td>
<td>Midland, TX</td>
<td>31.95</td>
<td>-102.18</td>
<td>872</td>
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<td>72357</td>
<td>OUN</td>
<td>Norman, OK</td>
<td>35.23</td>
<td>-97.47</td>
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<td>72456</td>
<td>TOP</td>
<td>Topeka, KS</td>
<td>39.07</td>
<td>-95.62</td>
<td>270</td>
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<tr>
<td>72349</td>
<td>UMN</td>
<td>Monett, MO</td>
<td>36.88</td>
<td>-93.90</td>
<td>437</td>
</tr>
</tbody>
</table>

MCLASS soundings:

The Cross-chain LORAN Atmospheric Sounding System uses Vaisala RS-80L LORAN radiosondes to profile temperature, pressure, humidity (Humicap) and winds. Thermodynamic parameters are transmitted directly from the radiosonde to the mobile laboratory every 4 sec. A 20-sec average every 10 seconds is archived for the thermodynamic variables, while a 30-sec average is used for winds. A WMO-coded message can be prepared and transmitted to the MEaPRS Operations Center, if needed. All CLASS data will be archived at NSSL. 10-sec sounding files will be available through the interactive data catalog.

MCLASS electrification:

As noted earlier in this document, five balloon-borne instruments to measure cloud electrification properties will be flown during MEaPRS. Unlike other data sources, there will not be a central archival site for these data sets. Interested collaborators should contact PIs (listed in section 5) for access to specific data sets. As such, there could be some delay with data availability.

OK Mesonet:

The Oklahoma Mesoscale surface Network (Oklahoma Mesonet) is operated by the Oklahoma Climatological Survey (OCS) and consists of 111 automated sites. 5-minute data are received at OCS, in Norman, Oklahoma, where they are quality controlled and archived. All mesonet sites measure the standard surface meteorological parameters, with some sites taking additional measurements from specialized instruments. Since some collaborative efforts are planned between OU and MEaPRS, arrangements could be made for the OCS to provide a complete data set to the MEaPRS archive.

GOES satellite imagery:

Satellite imagery is routinely ingested at NSSL and archived to tape. Visible and Infrared imagery are nominally available every 30 minutes, at 4-km resolution. The capability exists to acquire a high resolution (1-km) sector centered over the MEaPRS domain, if requested by researchers. Additionally, 12-km resolution images of water vapor channel are also available. These data are received from both GOES-8 and GOES-9 satellites.
Aircraft Data:

NOAA’s Aircraft Operations Center (NOAA/AOC, Tampa, FL) operates a Lockheed Orion WP-3D aircraft, a four-engine turboprop, which will be based out of Will Rogers World Airport at Oklahoma City. The P-3 will be available from 15 May to 15 June 1998 for approximately 50 research hours. The aircraft routinely measures flight level state parameters (temperature, moisture, winds) and basic microphysical variables (liquid water, PMS probe data) as well as data collected by its two radars. All aircraft data systems are recorded on 4-mm DAT media.

Flight-level Data:

Flight level meteorological data (temperature, moisture, winds) and other data systems from the P-3 will be collected, quality controlled and processed by the AOC. The data will be catalogued and archived at NSSL. CODIAC will have an inventory of take-off, landing times and could contain flight track information. The aircraft data manager will provide flight track information to the MEaPRS Field Catalog after each flight.

Aircraft Radar Data:

The NOAA WP-3D research aircraft carries two radars, the horizontally scanning lower fuselage (LF) radar and a vertically scanning tail (TA) radar. The LF radar is non-coherent and the TA radar is Doppler (3-cm). Both radars are three-axis stabilized, where the TA antenna is nominally directed perpendicular to the aircraft ground track but can be skewed fore and aft in order to perform pseudo dual-doppler scanning. Both antennas rotate a full 360°. Reflectivity and velocity data from the radars are recorded on 4-mm DAT media. The aircraft data manager, John Daugherty will provide a few radar summary images after each flight for documentation in the MEaPRS Field Catalog. All aircraft radar data will be available from the data manager after the field phase.

Cimarron Radar Data:

Cimarron data (reflectivity, radial velocity, spectral width, differential reflectivity, differential phase shift, and correlation coefficient) are continuously recorded during field operations on 8 mm DAT cartridges.

Lightning Network:

Cloud-to-ground flash information is routinely received at NSSL for the region centered on Oklahoma and Kansas from the Lightning Location and Protection (LLP/GAI) system. Data for time, location, polarity, signal strength and number of returned strokes are available for purchase at the end of the calendar year from Global Atmospherics, Inc.

Profiler Network:

Data from the Wind Profiler Demonstration Network are quality controlled by the NOAA Profiler Hub in Boulder, Colorado, archived at NCDC and can be accessed via the CODIAC system. Typically, high resolution (6-sec) data are kept on-line for 7 days and hourly data for 30 days.
Table 12: ERL Wind Profiler Demonstration Network Sites

<table>
<thead>
<tr>
<th>ID</th>
<th>Site</th>
<th>ST</th>
<th>Lat</th>
<th>Long</th>
<th>elev (m)</th>
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</thead>
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<td>CNW</td>
<td>Conway</td>
<td>MO</td>
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<td>DQU</td>
<td>DeQueen</td>
<td>AR</td>
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<td>GDA</td>
<td>Granada</td>
<td>CO</td>
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<td>1155</td>
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<td>HKL</td>
<td>Haskell</td>
<td>OK</td>
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<td>HVL</td>
<td>Haviland</td>
<td>KS</td>
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<td>-99.09</td>
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<tr>
<td>HBR</td>
<td>Hillsboro</td>
<td>KS</td>
<td>38.3</td>
<td>-97.29</td>
<td>447</td>
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<tr>
<td>JTN</td>
<td>Jayton</td>
<td>TX</td>
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<td>-100.98</td>
<td>707</td>
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<td>NRC</td>
<td>Kansas City</td>
<td>MO</td>
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<td>-94.57</td>
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<td>LMN</td>
<td>Lamont</td>
<td>OK</td>
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<td>Neodesha</td>
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<td>PAT</td>
<td>Palestine</td>
<td>TX</td>
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<td>PRC</td>
<td>Purcell</td>
<td>OK</td>
<td>34.97</td>
<td>-97.51</td>
<td>331</td>
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<td>TCU</td>
<td>Tucumcari</td>
<td>NM</td>
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<td>-103.61</td>
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<td>VCI</td>
<td>Vici</td>
<td>OK</td>
<td>36.07</td>
<td>-99.22</td>
<td>648</td>
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<tr>
<td>WSM</td>
<td>White Sands</td>
<td>NM</td>
<td>32.40</td>
<td>-106.34</td>
<td>1224</td>
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</tbody>
</table>

Model data:

Operational model-derived gridpoint data are available to NSSL researchers via the SPC data feed or the Unidata/Local Data Manager (LDM) feed. These files are routinely archived by NSSL/CSS staff. Data will be available, off-line, through the interactive data catalog. NSSL typically receives Eta and Ruc gridpoint data files in Gempak format.

MM5 at NSSL:

The NCAR / Penn State Mesoscale Model (MM5) is run at NSSL. Arrangements could be made for archival and distribution of MM5 grid fields, if requested by MEaPRS investigators.

9.2 Operations Summary / Field Data Catalog

NSSL, in collaboration with the UCAR Joint Office for Science Support (JOSS) has developed the capability of maintaining a World Wide Web (WWW)-based field data catalog. The on-line catalog capability allows investigators limited perusal and display of preliminary data products during the field phase. The catalog will also provide in-field project summaries (daily or otherwise as required) and summarize data collection activities. The field data catalog will provide access to daily operations and weather forecasts relating to MEaPRS activities. The NSSL field catalog can be reached at http://spider.nssl.noaa.gov/catalog/. The Web-based field catalog is also valuable in providing information to investigators that may be located away from the Operations Center.

A number of forecast / nowcast products will be available to the Operations Director and the Nowcaster at the MEaPRS Operations Center. The Operations Center will be housed in the SPC Science Support Area (SSA). Arrangements will be made for most products (excluding Cimarron products) received at the SSA workstations (N-AWIPS, RAMSDIS) to be copied to tape on a daily basis.

9.3 Interactive Data Catalog and Archive

Central to the NSSL data management is the on-line, interactive, catalog, archival and distribution system (CODIAC) which offers scientists a means to identify data sets of interest, the facilities to view selected data and associated metadata, and the ability to automatically obtain data from geographically dispersed data centers via Internet file transfer (FTP) or separate media (tapes, CD-ROM, disks, etc.). Links will also be provided from the NSSL CODIAC to other data centers holding cooperative project data and
other relevant information to MEaPRS research. The NSSL CODIAC system can be reached at http://codiac.nssl.noaa.gov/
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Appendix A

Organizations

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>AOC</td>
<td>Aircraft Operations Center</td>
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<tr>
<td>AOML</td>
<td>Atlantic Oceanographic and Meteorological Laboratory</td>
</tr>
<tr>
<td>ARS</td>
<td>Agricultural Research Service</td>
</tr>
<tr>
<td>CIAMS</td>
<td>Cooperative Institute for Applied Meteorological Studies</td>
</tr>
<tr>
<td>CIMMS</td>
<td>Cooperative Institute for Mesoscale Meteorological Studies</td>
</tr>
<tr>
<td>CSU</td>
<td>Colorado State University</td>
</tr>
<tr>
<td>DOD</td>
<td>Department of Defense</td>
</tr>
<tr>
<td>ERL</td>
<td>Environmental Research Laboratories</td>
</tr>
<tr>
<td>GAI</td>
<td>Global Atmospherics, Inc.</td>
</tr>
<tr>
<td>JMRF</td>
<td>Joint Mobile Research Facility</td>
</tr>
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<td>JOSS</td>
<td>Joint Office for Science Support</td>
</tr>
<tr>
<td>LANL</td>
<td>Los Alamos National Laboratory</td>
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<tr>
<td>MSFC</td>
<td>Marshall Space Flight Center</td>
</tr>
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<tr>
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<td>NOAA</td>
<td>National Oceanic and Atmospheric Administration</td>
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<tr>
<td>NSSL</td>
<td>National Severe Storms Laboratory</td>
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<td>National Weather Service</td>
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<td>Oklahoma Climatological Survey</td>
</tr>
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<td>OSF</td>
<td>NWS/WSR-88D Operational Support Facility</td>
</tr>
<tr>
<td>OU</td>
<td>University of Oklahoma</td>
</tr>
<tr>
<td>SPC</td>
<td>Storm Prediction Center</td>
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<tr>
<td>TAMU</td>
<td>Texas A&amp;M University</td>
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<td>UCAR</td>
<td>University Corporation for Atmospheric Research</td>
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<td>UM</td>
<td>University of Mississippi</td>
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## Appendix B

### Acronyms

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<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARM</td>
<td>Atmospheric Radiation Measurement</td>
</tr>
<tr>
<td>CASES</td>
<td>Cooperative Atmosphere-Surface Exchange Study</td>
</tr>
<tr>
<td>CODIAC</td>
<td>Cooperative Distributed Interactive Atmospheric Catalog</td>
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<td>COPS89</td>
<td>1989 Cooperative Oklahoma P-3 Studies (field project)</td>
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<td>COPS91</td>
<td>1991 Cooperative Oklahoma Profiler Studies (field project)</td>
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<tr>
<td>DSD</td>
<td>Drop Size Distribution</td>
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<tr>
<td>LAPS</td>
<td>Local Analysis and Prediction System</td>
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<tr>
<td>LDAR</td>
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<td>MCS</td>
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<td>MEaPRS</td>
<td>MCS Electrification and Polarimetric Radar Study</td>
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<tr>
<td>NGM</td>
<td>Nested Grid Model</td>
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<td>Plan Position Indicator</td>
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<td>Pressure-Temperature-Humidity</td>
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<tr>
<td>RADS</td>
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<td>RHI</td>
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