DOE/SC-ARM-14-035

Plains Elevated Convection at Night (PECAN) Experiment Science Plan

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DISCLAIMER

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Acronyms and Abbreviations

AERI	Atmospheric emitted radiance interferometers
AGL	Above ground level
CF	Central Facility
CI	Convection initiation
DIAL	Differential absorption lidars
DOE	Department of Energy
EOL	Earth Observing Laboratory
GSFC	Goddard Space Flight Center
IOP	Intensive observation periods
LLJ	Low-level jets
MCS	Mesoscale convective system
MSL	Mean sea level
MWR	Microwave radiometers
NASA	National Atmospheric and Space Administration
NOAA	National Oceanic and Atmospheric Administration
NPGS	Naval Post Graduate School
NSF	National Science Foundation
NWS	National Weather Service
PECAN	Plains Elevated Convection at Night
PI	Principal investigators
PISA	PECAN Integrated Sounding Array
SBL	Stable boundary layer
SGP	Southern Great Plains
SSC	Science steering committee
UWKA	University of Wyoming King Air

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1.0 Introduction

The Plains Elevated Convection at Night (PECAN) experiment is a large field campaign that is being supported by the National Science Foundation (NSF) with contributions from the National Oceanic and Atmospheric Administration (NOAA), the National Atmospheric and Space Administration (NASA), and the U.S. Department of Energy (DOE). The overarching goal of the PECAN experiment is to improve the understanding and simulation of the processes that initiate and maintain convection and convective precipitation at night over the central portion of the Great Plains region of the United States (Parsons et al. 2013). These goals are important because (1) a large fraction of the yearly precipitation in the Great Plains comes from nocturnal convection, (2) nocturnal convection in the Great Plains is most often decoupled from the ground and, thus, is forced by other phenomena aloft (e.g., propagating bores, frontal boundaries, low-level jets [LLJ], etc.), (3) there is a relative lack of understanding how these disturbances initiate and maintain nocturnal convection, and (4) this lack of understanding greatly hampers the ability of numerical weather and climate models to simulate nocturnal convection well. This leads to significant uncertainties in predicting the onset, location, frequency, and intensity of convective cloud systems and associated weather hazards over the Great Plains.

The PECAN experiment will be conducted over a large domain that encompasses most of western and central Kansas, northern Oklahoma, and southern Nebraska. A unique component of the PECAN observational strategy is the concept of the PECAN Integrated Sounding Array (PISA). Each PISA will have remote sensing instruments that can profile temperature, humidity, and winds throughout the boundary layer and lower troposphere at high time resolution (~5-min). Also, collocated radiosonde systems will be included in the PISAs. These radiosonde systems will provide detailed profile information at lower temporal resolution at all levels up to the lower stratosphere.

The domain will have six fixed PISAs (FP) and four mobile PISAs (MP). The mobile arrays are relocated nightly to augment the domain where convection is anticipated to occur. The Atmospheric Radiation Measurement (ARM) Facility Southern Great Plains (SGP) Central Facility (CF) serves as the FP in the southeastern cornerstone of the PECAN domain. A large number of instruments from the NSF Lower Atmospheric Observing Facility pool, university investigators, a private company, and other agencies such as NOAA and NASA will be used to instrument the other PISA sites. Detailed characterization of the thermodynamic and kinematic evolution of the boundary layer across the experimental domain will greatly enhance the rest of the observational data sets, which include fixed and mobile 3D scanning precipitation radars, mobile mesonet systems, clear-air and storm-penetrating aircraft, and mobile radiosonde-launching systems.

ARM is supporting the PECAN experiment by providing five atmospheric emitted radiance interferometers (AERIs), which will be deployed at the FPs in the domain. These instruments, together with the AERI at the SGP CF, will provide a uniform and consistent thermodynamic data set across the domain, which will greatly improve the ability of data assimilation schemes and other analysis techniques to characterize the thermodynamic environment and its evolution before and during these nocturnal events. Many recent studies have indicated that the lack of a spatial array of high temporal resolution thermodynamic profiles in the lower troposphere has been the limiting factor in understanding the processes at work in pre-convective and convective situations. Furthermore, ARM is providing a radiosonde station and consumables that will be used at one of the other FPs, thereby allowing all of the FPs to have radiosonde capabilities, and its vast array of sensitive radar and lidar profilers at the SGP CF (e.g., Raman lidar, Doppler lidar, 915 MHz wind profilers, etc.) will be used to investigate nocturnal convection when it occurs near that site. The full PISA data set will become publically available and will serve for many years as a leading mesoscale profiling network data set for data assimilation and prediction studies by DOE scientists and others. It will greatly augment the data set collected during the Midlatitude Continental Convective Cloud Experiment (MC3E), which focused on diurnal convection over the SGP.

2.0 Science Objectives

The focus of the PECAN experiment is to understand the processes at work in the initiation, growth, and evolution of nocturnal convective events over the Great Plains. Quite frequently, the surface is decoupled from the atmosphere above because of the nocturnal inversion; therefore, these processes are difficult to observe from the ground. This has resulted in a knowledge gap, which makes the forecasting and numerical modeling of nocturnal convection extremely suspect. Thus, the goal of the PECAN experiment is to gather data to improve our understanding of three particular events:

1. Initiation and early evolution of elevated convection
2. Nocturnal mesoscale convective system (MCS) structure and microphysics
3. Bores and wave disturbances in the nocturnal stable layer.

A fourth mission associated with attaining a better understanding of the formation and evolution of the nocturnal LLJ has also been established for the periods when convection is not anticipated to occur. The ultimate goal is to translate improvements in the understanding of the physical processes at work in these four events into improvements in our ability to model them using cloud-resolving and numerical weather prediction models.
Investigators involved in the PECAN experiment will test many specific hypotheses through the many proposals that have been funded by the NSF, NOAA, NASA, and other agencies. These specific hypotheses can be groups into four overarching hypotheses:

1. Nocturnal convection is more likely to be initiated and sustained when it occurs in a region of mesoscale convergence above the stable boundary layer (SBL).
2. The microphysical and dynamical processes in developing and mature stratiform regions of nocturnal MCSs are critical to their maintenance and upscale growth through determining the structure and intensity of cold pools, bores, and solitary waves that interact with the SBL.
3. Bores and associated wave/solitary disturbances generated by convection play a significant role in elevated, nocturnal MCSs by lifting parcels above the SBL to levels at or near their level of free convection.

A mesoscale network of surface, SBL, and upper-level measurements will enable advanced data assimilation systems to significantly improve the prediction of convection initiation (CI). Advances in quantitative precipitation forecasts associated with nocturnal convection will require either greatly improved convective parameterizations or, more likely, horizontal and vertical resolutions sufficient to capture both SBL disturbances and convection.

3.0 Observational Plan

The PECAN experiment will be held from 1 June to 15 July 2015 in western-to-central Kansas and north-central Oklahoma. This location and time of year was selected based on climatological studies of the frequency of occurrence of nocturnal MCS, propagating bores and gravity waves, LLJs, and nocturnal convective initiation (Geerts et al. 2013). During this 45-day period, at least 20 intensive observation periods (IOPs) will be conducted; an IOP is defined as a period of coordinated deployment of all mobile and airborne PECAN facilities. An IOP will typically start around sunset and will last 4 to 8 hours. Based on a climatological analysis over the central portion of the United States, a total of 20 IOPs are needed to achieve the objectives of the PECAN experiment (Geerts et al. 2013).

The PECAN observational strategy is to use a suite of fixed and mobile instruments to observe the thermodynamic and kinematic evolution of the late daytime and nocturnal boundary layer and mid-troposphere, as well as the evolution of the cloud and precipitation microphysics and the precipitation field, over the PECAN domain. The PECAN observational plan calls for three aircraft: the NSF University of Wyoming King Air and the NASA DC-8 will probe the pre-convective environment, and the NOAA P-3 will study the microphysical characteristics of developing and mature stratiform regions of MCSs. All three airborne platforms are funded, although the P-3 is only available after the middle of June and the DC-8 is only available for the last three weeks of the campaign. The PECAN experiment will deploy mobile scanning Doppler radars and lidars, mobile mesonet and radiosonde systems, and profiling sensors such as water vapor differential absorption lidars (DIAL) and Raman lidars, multi-channel microwave radiometers, infrared spectrometers, and acoustic systems. In particular, the National Center for Atmospheric Research (NCAR) S-Pol radar will be deployed in Hays, Kansas, to fill in the gap in the S-band radar coverage provided by the National Weather Service (NWS) WSR-88D radars (see Figure 1), and the mobile C- and X-band radars will be positioned around the domain based upon the forecast for each particular event in an attempt to provide the best observations of the precipitation and wind structure during each evening. A typical deployment strategy has the seven mobile radars positioned in a hexagon structure with one radar vehicle in the center, with the MPs positioned around this hexagon to monitor the thermodynamic and kinematic environment as the target of interest (e.g., MCS, bore, etc.) propagates overhead.

A unique aspect of the PECAN experimental design is its incorporation of the thermodynamic and wind profiling systems into the PISA system. Each of the 10 PISA units will be highly complementary in their capability to profile wind, thermodynamics, water vapor, and aerosols at high temporal resolution, which allows the evolution of the boundary layer and propagating features to be observed. The key goals of the PISAs, generally in concert with the airborne and surface measurements, are to describe:

1. The evolution of the static stability, low-level humidity, convective inhibition, and most-unstable convective available potential energy to quantify CI potential, MCS potential energy, and MCS-relative shear, and the coupling strength of MCS cold pools and their boundaries (density currents or bores) with the underlying surface across the SBL
2. The evolution of the lower-tropospheric wind and turbulence profiles to quantify moisture transport, mesoscale convergence, and nocturnal LLJ-SBL interactions
3. The essential structure and evolution of undular bores and solitary waves, in terms of vertical and horizontal winds, and displacement of isentropic and moisture layers in the lower troposphere.

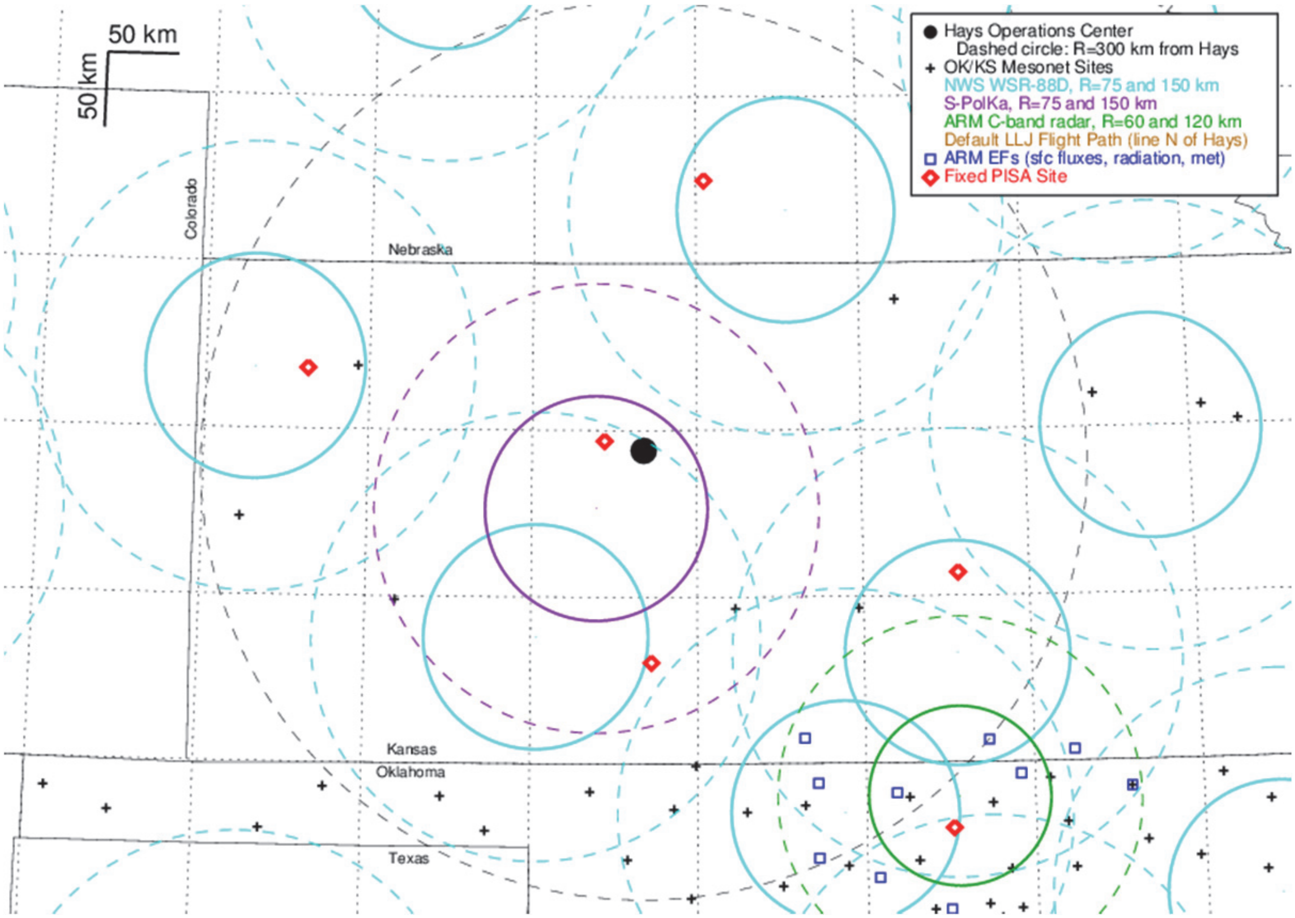

Figure 1. Locations of Fixed PISAs (red diamonds) Relative to the Location of the S-Band Radars (cyan circles are for the NWS radars, the purple circle is the S-Pol radar, where solid and dashed lines are for 75 and 150 km radii, respectively). Range rings around the ARM C-band radar are the green circles, with radii of 60 and 120 km. ARM extended facilities are denoted with blue squares, and mesonet stations in Oklahoma and Kansas are the black crosses.

There will be six FPs and four MPs that can be moved around the PECAN domain (similar to the mobile radar resources) to provide the best observational coverage for each particular evening. While no two PISAs have exactly the same instrument complement, each system will have the following measurement capabilities:

1. Surface meteorological observations.
2. Upper air in situ data from radiosondes launched nominally every 3 hours during the operational night-time periods to characterize the thermodynamic and wind structure of the middle to upper troposphere at each site.
3. Remotely sensed wind profiles (u, v, and w). Some PISAs will use wind profiling radars (400 to 915 MHz) that are all weather capable but have relatively poor temporal and vertical resolutions, while others will use Doppler lidars that have much higher temporal and vertical resolution but are limited to regions below clouds in the boundary layer.

4. Remotely sensed temperature and humidity profiles. This will be achieved using a range of different instruments, including multi-channel microwave radiometers (MWRs), AERIs, Raman lidars, and DIALs. The lidars are able to measure water vapor at high vertical resolution up to the cloud base, or throughout much of the troposphere if the sky overhead is cloud free. The lidars also are sensitive to aerosol properties, which is useful for identification of different atmospheric layers that can exist in the nocturnal boundary layer. The AERIs and MWRs are passive remote sensors that have lower vertical resolution than the lidars, but are able to simultaneously retrieve temperature and humidity profiles. The AERI provides two to three times more information, and thus higher vertical resolution, than the MWRs (Löhnert et al. 2009). A recent advance described by Turner and Löhnert (2014) allows profiles to be retrieved from the AERI in all non-precipitating conditions.

ARM's contribution is primarily to augment the PISA systems, and to serve as FP-1 among 10 PISA systems that are identified in Table 1. Many of the PISA systems use instruments from different institutions to ensure that the essential variables are being observed at each PISA site. Most of the instruments are currently in operation or have been already used extensively in field campaigns; the exceptions are the ISS-449 and the mini-water vapor DIAL, which are brand new instruments, and the mobile system MP-1, which is currently under construction. The abbreviation "ISS" stands for integrated sounding system, each of which includes a wind profiling radar (the number after the abbreviation ISS is the frequency in MHz of the radar).

It is anticipated that all of the FPs will operate continuously throughout the duration of the PECAN experiment. One of the FP stations is the SGP CF, which serves as an anchor in the southeast corner of the PECAN domain. The other FPs will be stationed approximately 200 km apart from each other (see Figure 1). The objective of the FPs is to provide the larger scale context of the evolution of the boundary layer during the experiment. A key component of the FP observational strategy is deployment of AERIs at each of these sites, with thermodynamic retrievals being accomplished using the algorithm developed by Turner and Löhnert (2014) to provide a baseline that has consistent sensitivity and capability across the domain.

Table 1. PISA Systems for the PECAN Experiment. The instruments provided by ARM are indicated in blue text.

ID	Closest Town	Lead Investigator	Instrument Source	Instruments
FP-1	Billings, Oklahoma	Dave Turner	ARM SGP CF	Doppler lidar, Raman lidar, AERI, radiosondes, surface met and fluxes, four 915 MHz profilers, C-SAPR
FP-2	Greensburg, Kansas	Qing Wang and Belay Demoz	Naval Post Graduate School (NPGS), Howard University, NASA Goddard Space Flight Center (GSFC), and DOE	Raman lidar, Doppler lidar, backscatter lidar, AERI, microwave radiometer profiler (MWRP), radiosondes, sonic detection and ranging (sodar), surface met and fluxes
FP-3	Ellis, Kansas	Rich Clark and Bill Brown	NCAR Earth Observing Laboratory (EOL), Millersville University, University of Hohenheim, DOE, University of Manitoba	ISS-449, NCAR mini-water vapor DIAL, AERI, radiosondes, MWRP, Doppler lidar, surface met
FP-4	Minden, Nebraska	Bill Brown	NCAR EOL, DOE	ISS-915, AERI, sodar, radiosondes, flux tower, surface met
FP-5	Brewster, Kansas	Bill Brown	NCAR EOL, DOE	ISS-915, AERI, sodar, radiosondes, surface met
FP-6	Hesston, Kansas	John Hanesiak	University of Manitoba, DOE	AERI, MWRP, Doppler lidar, radiosondes, surface met
MP-1	(mobile)	Dave Turner	National Severe Storms Laboratory, University of Oklahoma	AERI, MWRP, Doppler lidar, radiosondes, surface met
MP-2	(mobile)	Kevin Knupp	University of Alabama – Huntsville	MWRP, Doppler lidar, 915 MHz profiler, sodar, ceilometer, radiosondes, surface met
MP-3	(mobile)	Wayne Feltz,	University of Wisconsin – Madison	Doppler lidar, AERI, radiosondes, surface met
MP-4	(mobile)	Bill Brown	NCAR EOL	Mobile ISS-915, radiosondes, surface met
Notes: FP = fixed PISA MP = mobile PISA				

Details of the instrumentation at each of the FP sites are listed below:

- FP-1. This is the ARM central facility and closely located instrumentation (i.e., C- and X-band scanning precipitation radars). This is by far the most complete PISA site in the PECAN domain. *The highest priority instruments at the ARM SGP CF are the C-band precipitation radar, the 915-MHz radar wind profilers, the Doppler lidar, the Raman lidar, an AERI system, an MWRP, the eddy covariance system, and the cloud radar. ARM also will launch radiosondes every 3 hours from 21 UTC to 12 UTC at the SGF CF each evening though the PECAN experiment period.*
- FP-2. Instrumentation for this site is primarily coming from Howard University, the NPGS, and NASA GSFC. In particular, NASA will deploy its Atmospheric Laboratory for Validation, Interagency Collaboration, and Education Raman lidar (very similar to the ARM Raman lidar) and the Goddard Lidar Observatory for Winds Doppler lidar to the site to complement the MWRP, sodar, surface measurements, and radiosonde system that will be provided by NPGS and Howard University. *ARM also will deploy an AERI system to augment the observational capabilities at this site*.
- FP-3. This site will feature a 449-MHz wind profiler that is under development now at NCAR EOL, as well as a low-power water vapor DIAL system under development at NCAR. *ARM is providing an AERI system for this site* to complement the water vapor observations from the DIAL and to provide high temporal resolution temperature profiles. Note that Millersville University will be providing the radiosonde system, tethersonde, sodar, and surface flux station for this site, and a zenith pointing Doppler lidar from the University of Manitoba also will be deployed here.
- FP-4 and FP-5. Both of these sites are being outfitted with instruments from the NCAR EOL pool. They will include the ISS, which consists of a 915-MHz radar wind profiler, a radiosonde system, a surface meteorological station, and a sodar. *ARM will deploy an AERI for each of these two sites to provide the high temporal resolution thermodynamic profiling capability*.
- FP-6. The instrumentation for this site is being provided by the University of Manitoba, and will include a scanning Doppler lidar, an MWRP, and a surface meteorological station. *ARM will provide an AERI system, a radiosonde ground station, and 150 radiosondes (including balloons and helium) that will be launched from this site*.

Recently, Kennedy (2011) demonstrated that there was a moist bias in the boundary layer in the continuous large-scale variational analysis product produced by ARM for the SGP region; this product is highly dependent on the mesoscale analysis fields used as the background as there is a lack of additional water vapor (and temperature) profilers in the region. We believe that the deployment of multiple AERI systems into this domain will greatly improve the accuracy of the derived variational analysis data set, which will be a critical product that arises from this experiment. The reason for this is the accuracy of the AERI's calibration process and the use of a single algorithm (i.e., the algorithm developed by Turner and Löhnert [2014]) to retrieve the thermodynamic profiles from the AERI spectra. Furthermore, AERI provides two to three times more information on the temperature and humidity profiles (Löhnert et al. 2009) than the MWRP, although the microwave profiler may be able to provide more information above the cloud base, which makes it desirable to have both AERI and MWRP systems collocated if possible.

The MPs and the mobile precipitation radars will be deployed to any of a set of pre-selected sites within the PECAN domain in the late afternoon before a PECAN IOP commences, and will remain stationary during the IOP. The locations selected will be based on the objective of the experiment for the evening (i.e., what is the focus of the experiment: convective initiation, bore propagation and impacts, MCS development, or LLJs) and the forecast, but the primary goal of the MPs is to provide additional spatial coverage in the gaps in the FP array for particular events. Confinement of the MPs to a single location during any evening mission will maximize data quality, integration with the fixed array, value for the variational analysis, and safety in the night-time deployment.

4.0 Operations Plan

4.1 Fixed Sites

The PECAN domain encompasses central and western Kansas, as well as adjacent parts of mainly Nebraska and Oklahoma (Figure 1). Its location is driven by climatological information (Geerts et al. 2013). Its size is determined by the maximum driving distance from Hays, Kansas, (i.e., ~350 km) for mobile units anticipated to be used during an IOP. The elongated shape along its north-south orientation is explained by persistent meridional variations in MCS tracks, and by accessibility and site quality for mobile ground-based scanning systems. The PECAN domain has reasonable low-level radar coverage (a 0.5° elevation radar beam is ~1.2 km above radar elevation at a range of 75 km), mainly in the southeastern sector because of the ARM radars. Coverage is lacking in the central PECAN domain near HYS, which affected our choice to locate S- Pol near Hays. The FPs are distributed in the domain at a typical spacing of 200 km, and each is within 75 km of at least one S-band radar. The FPs and S-band radars will operate continuously throughout the PECAN experiment, thus providing a rich data set and also capturing the afternoon-evening and morning transition periods. The southern FPs are more likely to "participate" in bore missions, the western FPs in CI missions, and the eastern FPs in MCS missions.

4.2 Convective Initiation Missions

The CI missions initially will target regions of mesoscale convergence above the SBL (Figure 2). In some cases, CI is expected on the cold side of a low-level synoptic baroclinic zone, within the exit region of the elevated LLJ, as in Figure 2. In other cases, a baroclinic zone will not exist. The optimal deployment of seven mobile radars is in a hexagonal array with one radar in the center of the hexagon. The mobile soundings and PISA units are positioned to allow for Bellamy Triangle calculations of basic kinematic fields (Spencer et al. 2003). The exact facility layout will differ somewhat, depending on the density of pre-selected sites. The MPs are deployed along a line normal to the convergence line and spaced ~35 km apart. The University of Wyoming King Air research (UWKA) aircraft and the DC-8 fly racetrack patterns across the pre-convective convergence line. The UWKA racetrack pattern initially will be ~100 km long, and the DC-8 pattern will be 200 to 300 km long. If a well-defined convergence line is encountered, the length of the pattern will be decreased. In case of CI, sampling will continue for a period of 1 to 2 hours to quantify the upscale growth process toward an MCS stage, but only if the system is slow-moving. Mobile observations will continue as long as useful, but the PECAN array will not be repositioned to track the possible upscale growth from isolated deep convection to MCS initiation, given the typical time and space scales of such growth.

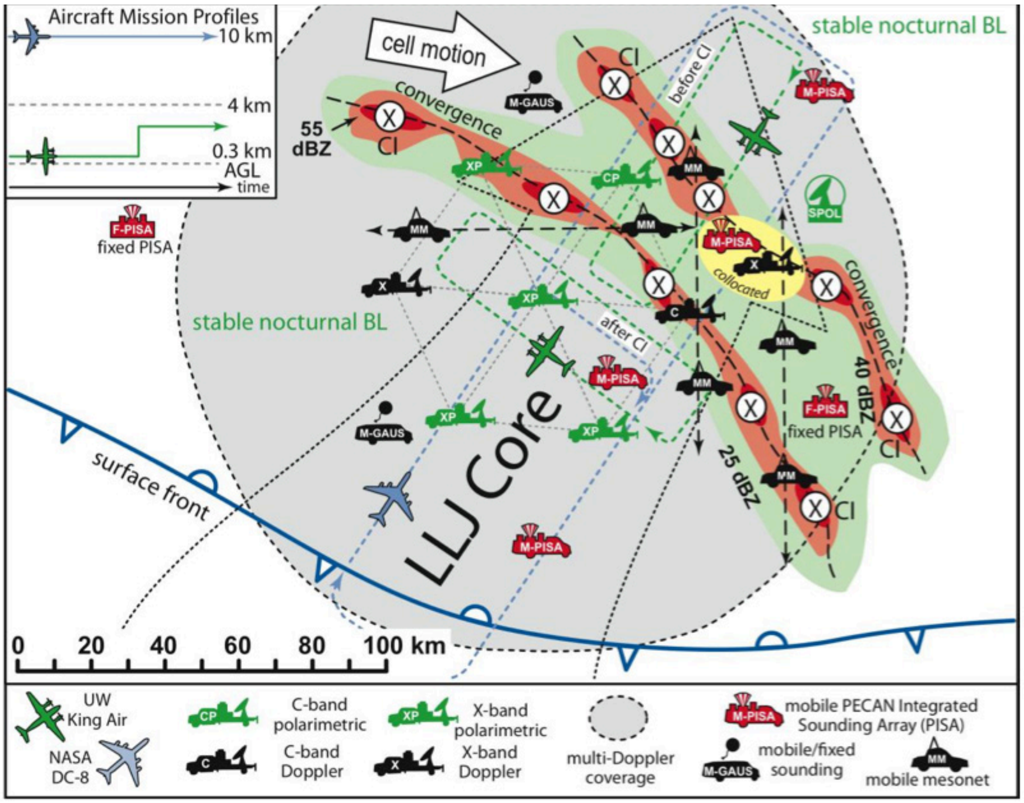

Figure 2. CI Deployment Strategy (Geerts et al. 2013). The mission starts well before anticipated CI, based on model and human forecast guidance, and flight operations are modified to sample the convection-relative inflow area and the LLJ (if present) during the post-CI period. Radars and PISA units remain in a fixed deployment, with some pre-CI adjustment possible based on real-time evidence for preexisting convergence lines.

4.3 MCS Missions

In an MCS mission, mobile units are deployed ahead of a recently formed MCS that is predicted to be long-lived (Figure 3). The mobile radars are positioned in a hexagonal pattern with the C-band radars closest to the approaching MCS. The MPs are positioned along the line of MCS centroid migration, with a characteristic spacing of ~35 km between units. The rapid-scanning, X-band (3-cm wavelength), polarimetric radar will be deployed in close proximity to MP-3. The UWKA will fly across the outflow boundary in a square tooth pattern with boundary-normal legs ~50 km long, mainly covering the multiple Doppler hexagon. Once a bore/wave structure is encountered, a narrow racetrack pattern with a leg length of ~50 km will be flown to capture the evolution of the structure at flight levels ranging between 1000 ft above ground level (AGL) and 3 km above mean sea level (MSL). The DC-8 will fly an equally narrow racetrack pattern normal to the outflow boundary, with one of the legs corresponding with the line of MP units. Narrow racetrack patterns maximize the temporal resolution as return visits are faster than a 90 to 270° turn, and along-wave uniformity can be assumed over a short lateral displacement. The NOAA P-3 will penetrate the stratiform and transition regions of the MCS, with spiraling descents and ascents at flight levels ranging between 0.3 and 6 km AGL. The P-3's flight levels are shown in the insert in Figure 3. One leg at a level of ~5 km will follow the length of the squall line in the transition region under guidance of real-time, lower-fuselage radar reflectivity imagery. The P-3 flight pattern improves on experience gained in the Bow Echo and MCV Experiment by greatly increasing the number of spiral ascent and descent maneuvers to better profile the rain and ice regions of target MCSs.

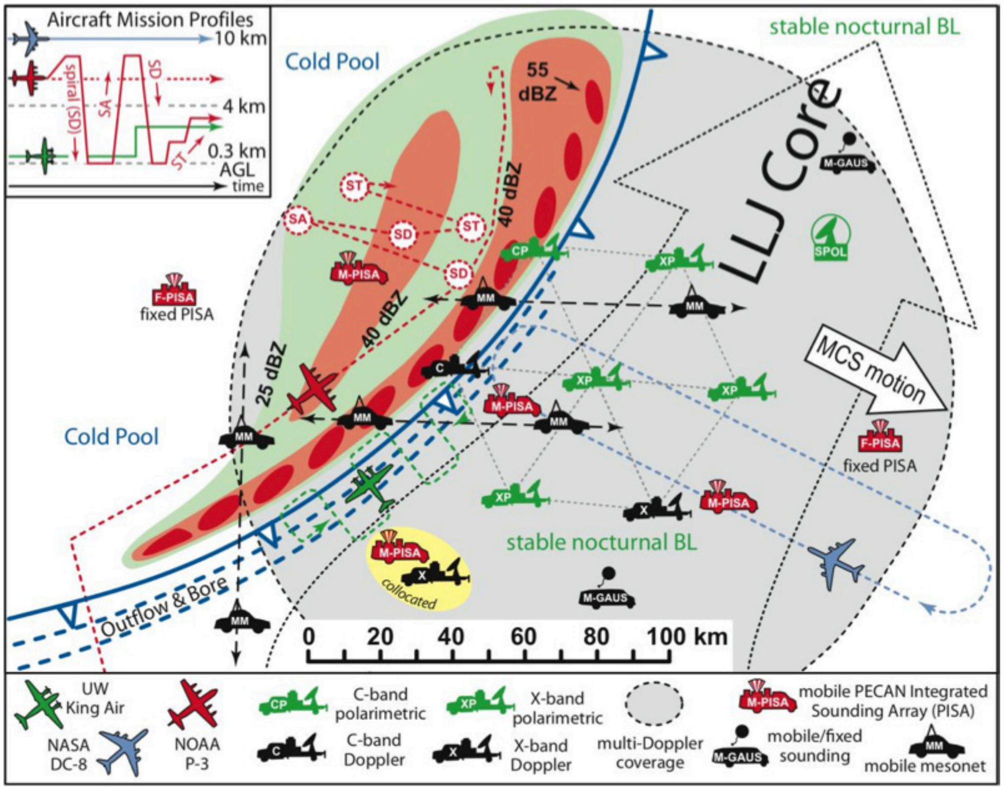

Figure 3. MCS Deployment Strategy (Geerts et al. 2013). The mission starts around the time that widespread convective storms have developed and begun to cluster (given forecasts indicating a high likelihood of conditions supporting development of persistent MCSs given widespread storms). Radars and PISAs remain in a fixed deployment, while the other mobile platforms adjust for system motion. In the insert, SD = spiral descent, SA = spiral ascent, and ST = stepped transverse.

4.4 Bore Missions

The bore missions are designed to determine why bores form, how they evolve, how they interact with the environment, and how they influence convection. The bore missions will target the southern and southeastern regions of MCSs (Figure 4). While bores are equally likely to emanate outward in other directions, the bores with a more zonal orientation will favor a continuation of convective activity north of the bore likely due to because of favorable MCS inflow produced from the interaction between the LLJ and the ascent produced by the bore. The DC-8 with the **Lidar Atmospheric Sensing Experiment** is important for mapping the large-scale environmental moisture field and detecting the net upward displacement by the bores. The UWKA also will profile the bore, but at a higher frequency, and will provide in situ thermodynamic and kinematic information between 1000 ft AGL and 3 km MSL. Mobile soundings and profiles from the FPs and MPs in advance of and during passage of bores are critical to sampling the vertical profiles of wind and stability in the lower troposphere in advance of the bores, as well as the bore structure. These data will be used to determine how the bore ascent modifies the air to feed into the trailing convection or MCS. The fixed and mobile radars will help determine the relationship between the bores and the structure of the trailing convection including the generation of new cells and new convective outflows. Mobile radar clear-air signals (mostly from insects) will be used to observe the bore structure, scale, horizontal and vertical extent.

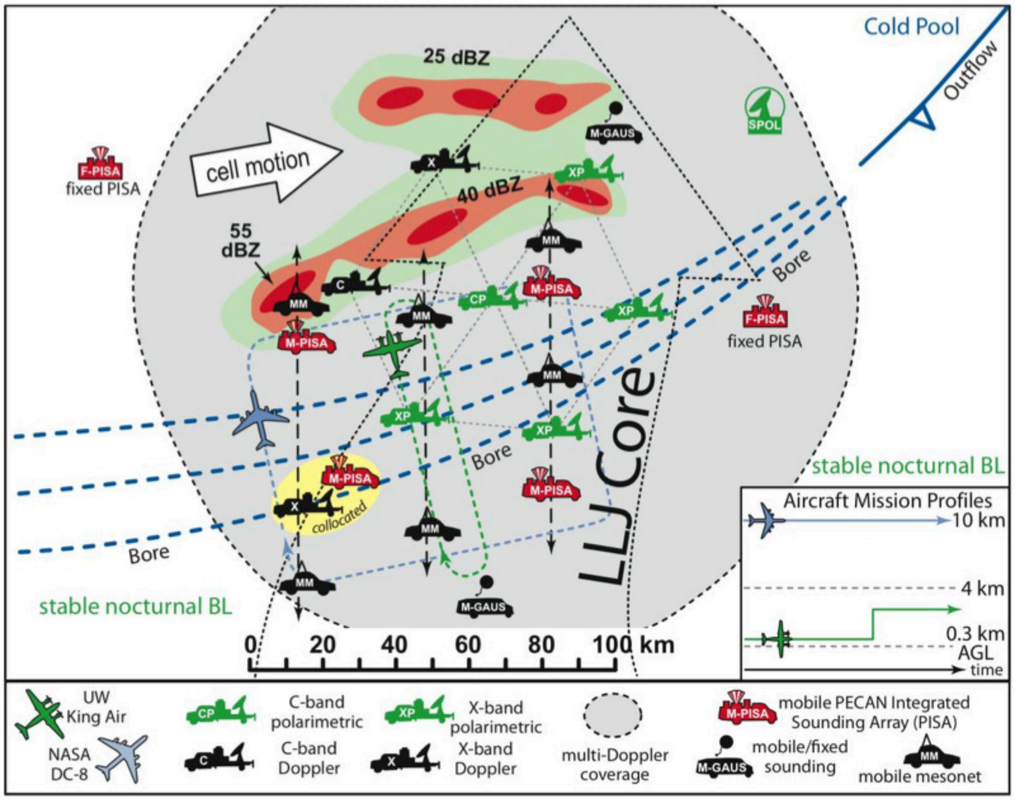

Figure 4. Bore mission Deployment Strategy (Geerts et al. 2013). The same hexagon mobile radar array is used, and mobile PISAs are positioned to optimize bore passage sampling in the multi-Doppler domain. The mission starts before bore emergence based on maximum wind speed occurrence. In case S-Pol is close to the target bore, one of the MPs with Doppler scanning lidars (i.e., MP-1, -2, or -3) will be collocated with S-Pol to compare S-band radar to lidar coverage of bore vertical displacements.

4.5 LLJ Missions

Missions to study initiation and evolution of the LLJ are lower priority missions relative to the other three missions; therefore, the LLJ mission is considered the null mission if the synoptic situation and forecast suggests that none of the other three missions are likely. In this case, the four MPs will deploy along a line from east-to-west with FP-3 in the center. The four MPs and the six FPs will collect data from late afternoon until sunrise. The spatial distribution of the PISAs will provide the first detailed investigation of how the LLJ evolves over the night, how it interacts with the formation of the nocturnal SBL, and if/how the sloping terrain from west-to-east impacts the evolution of the LLJ.

4.6 ARM Assets

Discussions of detailed operational plans for each instrument or investigator are beyond the scope of this document. Thus, only the activities of the ARM instruments will be described in this section.

The AERIs that are deployed at the FPs will be run in an autonomous mode; the objective is to collect infrared radiance data from which thermodynamic profiles can be retrieved continuously throughout the PECAN experiment. The lead investigator for each FP will be trained to monitor the real-time AERI display, and Dave Turner and the AERI mentors will monitor these instruments remotely. After the experiment, Dave Turner will quality control the data, apply a noise filter algorithm to reduce the random error, and then retrieve thermodynamic profiles (Turner and Löhnert 2014). These data sets will be placed in the ARM data archive, and shared with the investigators involved in the PECAN experiment.

The ARM radiosonde system stationed at the FP-6 site in Hesston, Kansas, will be monitored by scientists and students from the University of Manitoba (who are the lead investigators at this site). They will be responsible for launching the ARM-provided radiosondes on the schedule dictated by the PECAN Mission Science Team (see project management section below). The raw radiosonde data will be ingested into netCDF, placed in the ARM data archive, and shared with the PECAN investigators.

The ARM SGP CF site will operate normally, with the exception of the extra radiosonde launches at 21, 3, and 9 UTC during the 6-week PECAN experiment period. However, a higher priority will be placed on ensuring that critical instruments such as the Raman lidar, Doppler lidar, AERI, C-band scanning radar, 915-MHz wind profilers, surface met, and surface flux (i.e., Eddy Correlation Flux Measurement System and Energy Balance Bowen Ratio Station) instruments are operating properly.

5.0 Project Management

The PECAN field experiment is a large effort that involves multiple agencies and investigators. To coordinate the development of the project, a science steering committee (SSC) has been created to develop the scientific objectives of the experiment, devise initial observational and data management plans, coordinate meetings and communications with other scientists and staff affiliated with the project, and interface with program managers at the different agencies (NSF, NOAA, NASA, DOE). Drs. Geerts and Parsons are the PIs of the PECAN project and are the chairs of the PECAN project SSC. Thus, they are familiar with all aspects of the project. Dr. Turner is the coordinator of all of PISA systems for the PECAN experiment.

During the experiment, there will be an Operations Center located in Hays, Kansas. A Mission Science Team will decide on the mission for each day. The Mission Science Team will be responsible for real-time coordination among the SSC, forecasters, aircraft facilities and FAA/ATC, and mobile units (e.g., PISAs, radars, mesonets, etc.), starting from the decision to deploy assets to the safe return of the assets after the nightly a mission. Activities at the Operations Center will include daily project planning meetings (with many attendees interacting remotely) and operations support activities through the dissemination of critical project planning information. Coordination of ground-based mobile and airborne assets will be initiated at the Operations Center to maximize flexibility in sampling location and strategies.

Staff from the National Severe Storms Laboratory and investigators by the PECAN project will provide dedicated forecast and "now-cast" guidance. Specific ingredients-based, real-time analysis tools will be developed and tested in advance, in support of the four mission types (i.e., CI, bores, MCSs, and LLJs). Both operational models and PECAN-specific simulations by university modeling centers (e.g., Center for Analysis and Prediction of Storms at the University of Oklahoma) will be used. Data collected during the PECAN experiment, especially the soundings, will be incorporated in the data stream for assimilation into these models. These forecasts will be used by the SSC to inform decisions that will be made on a daily basis as to which location has a reasonable probability of developing MCSs and CI that can be targeted for study. Decisions must be made far enough in advance so that the mobile ground assets can get into position to collect needed data and to properly coordinate with FAA/ATC authorities. The bases for these decisions are described below:

- Evaluation of weather forecasts (presented by the forecasting team either in person or by video-teleconference)
- Real-time evaluation of information from radars, satellites, and other real-time operational observing systems; evaluation of the readiness of the aircraft and ground-based mobile facilities in consultation with the facility managers
- Consideration of the appropriate balance between the nocturnal MCS, bores, elevated CI, and LLJ themes needed to address the overall scientific objectives of the experiment.

6.0 Data Management Plan

Data collected during the PECAN experiment will consist of observations from its field campaign, auxiliary data from operational sources, and output from numerical model simulations. The data management strategy includes the following elements:

1. Use of questionnaires to collect information and preparation of a Data Management Plan that defines data requirements and provides a comprehensive data management support strategy prior to the field phase
2. Collection of special high-resolution data sets in real-time and the post-field phase (e.g., GOES satellite data; NWS soundings; WSR-88D radar; ARM datasets)
3. Set-up and support of a project data management website and distributed long-term PECAN data archive
4. Quality control and post processing of operational and research data necessary to the development of common format datasets for soundings and surface stations
5. Creation of radar data mosaics using common format radar data.

The PECAN project website and archive will be located at NCAR EOL. This centralized archive site will allow investigators to archive data and metadata at a single location or provide links to alternate archive sites.

The EOL is currently designing and will soon implement a PECAN Field Catalog customized to meet project needs for in-field documentation. The Field Catalog will be a web-based central repository of project planning documents, mission reports, facility status updates, field data images, satellite and model products, and other information that are all invaluable for in-field decision-making and post-project reference. The catalog will help the project document activities in near real-time, provide a single point for updating status, and provide a repository for preliminary in-field research data products. The Field Catalog will be further used after the field phase to assist in data analysis and to provide a long-term record of the project. Project participants will work with the EOL to prepare and test web-based forms that will provide the basis of in-field documentation. These documents will include the daily operations summary, daily facility status reports, expendable resources status reports, and daily weather forecasts.

The development and maintenance of a comprehensive and accurate data archive is a critical step in meeting the science objectives of the PECAN project. The primary data archive will be at NCAR EOL. The NCAR EOL data stewardship will ensure long-term integrity of the data. The PECAN principal investigators (PI) and EOL staff are developing a data management strategy by following data policies, data format requirements, and protocols consistent with NSF guidelines. This includes providing metadata, data and documentation as soon as possible following the end of the field phase (i.e., typically within one year). Assistance also will be requested to implement a process for PECAN submission and archival, and to provide specialized data collection and processing support and to design a distributed archive. The entire PECAN experiment data set will be available only for PECAN PIs for 1 year after the release of the quality-controlled data set. Thus, only PECAN PIs and their collaborators will have data access during the first year. After the first year, the entire data set will be open to the general scientific community.

Dr. Turner will be responsible for data quality control of the ARM-deployed instruments at the PECAN sites (other than FP-1, which would still fall under the normal ARM data quality control paradigm of mentors and the data quality office). Dr. Turner would process the AERI data to provide thermodynamic profiles, and would ensure that these profiles are archived in both the EOL and ARM data archives. All other ARM-supported raw and processed data from PECAN would also be stored in the IOP portion of the ARM archive.

7.0 References

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