PECAN OPS PLAN

1. Project Overview (Geerts/Ziegler/Weckwerth)

1.1 Scientific Objectives

PECAN aims to advance the understanding and forecast skill of the processes that initiate and maintain nocturnal convection in the Great Plains. Specifically, the four interconnected PECAN foci are:

1. Initiation and early evolution of elevated convection: This component seeks to advance knowledge of the processes and conditions leading to pristine nocturnal CI and the initial upscale growth into MCSs. This goal will require the observing of mesoscale processes such as diabatically forced deep-tropospheric gravity waves, PV anomalies, and frontogenetic circulations that drive mass convergence and alter the vertical profile of stability and/or shear. Unique to PECAN is the focus on finer-scale processes, such as bores, solitary waves, and parent solenoidal circulations that are known to dominate convergence and CI in the daytime convective BL. Key questions include: How do these disturbances lift layers to a depth sufficient to overcome convective inhibition (CIN) and to surpass the level of free convection (LFC), both at night when the SBL is well-established, and during the evening when the lower boundary stabilizes? How do these disturbances affect turbulent exchanges across the SBL? How does this stabilization produce an environment that facilitates upscale growth of cellular convection and the evolution of the kinematic and microphysical properties of embryonic MCSs?

2. MCS internal structure and microphysics: This focus addresses the kinematic and dynamical structure and the microphysics of nocturnal MCSs, including impact of storm- and mesoscale downdrafts, rear-to-front flow, SBL erosion, cold pool spreading, bore formation, and the change from gust front based to elevated convection. Both persistently-elevated convection and transitions from surface-based to elevated and vice-versa will be examined. Key questions include: what are the hydrometeor size distributions and proportions of rimed and unrimed ice particle habits, and how well are particle types captured by the WSR-88D particle ID algorithm in MCSs? How can microphysical processes in developing/mature convective and stratiform regions of MCSs drive downdraft circulations that can depress or erode the SBL and produce waves on the SBL and bore-initiating outflow boundaries? What is the relation of the thermal and dynamic characteristics of MCS cold pools to the physics of evaporation and sublimation of particles in dry air in low- and middle levels of the MCSs? How does the vertical profile of latent cooling influence the vertical structure of wave/bore generation?

3. Bores and wave-like features: This component seeks new knowledge of how the mesoscale environment modulates the initiation, propagation, and demise of bores and other trapped wave disturbances that originate from convective cold pools and seeks to determine the inherent role of these systems in nocturnal MCSs. PECAN aims to detect and understand bores propagating away from their parent cold pool and those that remain an integral part of MCSs. The key question is to what extent bores and/or solitons play a role in the initiation and maintenance of elevated MCSs in the presence of a SBL through lifting isentropic layers to their LFC.

4. Storm- and MCS-scale NWP: This focus area will use the PECAN observations to improve prediction of nocturnal CI, MCSs, and, more generally, the diurnal cycle of warm season precipitation in the Great Plains. The work will range from MCS-scale cloud-resolving LES models, to convection-allowing NWP models, to coarser-resolution NWP models with convective parameterizations, and to global climate models. To accomplish this goal, the project will require evaluation of operational and research models at high resolution operating in real-time as well as the use of idealized simulations to isolate important dynamical and physical processes. Data assimilation experiments will be conducted to determine the observational strategies required for improving predictions and providing a robust technical basis for recent efforts to develop strategies to improve the national observing network and to build a new-generation national profiler network replacing the 404 MHz wind profilers, such as outlined in the 2009 NRC study "Observing Weather and Climate from the Ground Up: A Nationwide Network of Networks".

The three observational foci require a network of scanning Doppler radars to describe clear-air features, precipitation, and the flow field within, and a network of profiling or volume-scanning remote sensors sufficiently sensitive to monitor wind profiles and detect isentropic/humidity disturbances within and above the SBL, both in clear air and in cloud/precipitation. This network should have an elastic density to sufficiently map out the heterogeneity of the SBL and overlying high-momentum isentropic layers and the capability to zoom in and capture transient and/or propagating disturbances.

PECAN will have many specific hypotheses through its many proposals to NSF and elsewhere. The four overarching hypotheses (corresponding to the four foci) PECAN will be testing are as follows:

1. Nocturnal convection is more likely to be initiated and sustained when it occurs in a region of mesoscale convergence above the 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 through lifting parcels above the SBL to levels at or near their level of free convection.
4. A mesoscale network of surface, boundary-layer and upper-level measurements will enable advanced data assimilation systems to significantly improve the prediction of convection initiation. Advances in QPF 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.

1.2 Study Region and Field Period

The PECAN field phase is from 1 June to 15 July 2015 (45 days). The time of year is fairly inflexible, given climatological considerations (Section 1.3). The field phase duration is motivated by the target number of intensive observation periods (IOPs). An IOP is defined as a period of coordinated deployment of all mobile and airborne PECAN facilities. An IOP typically will start about 1 hour after sunset, and last 4-8 hours. It may start as early as ~1 hour before sunset, as a SBL often has developed by then, and may end just after sunrise, but is typically concentrated within the ~9 hour period from sunset to sunrise.

A total of 20 IOPs are needed to achieve PECAN's objectives. *Ten IOPs will focus on MCSs, 5 on CI, and 5 on bores*. Most IOPs will accomplish multiple IOP objectives, e.g. CI may be targeted as the BL stabilizes in the evening; and the MCS missions will also target any MCS-spawned bores. Clearly CI and MCS missions are distinct, both from forecast and deployment strategy perspectives. On average one IOP will be conducted every 2nd or 3rd night, although several consecutive IOP nights can be expected given the relatively slow progression of synoptic conditions. Not all IOPs are expected to witness CI, a long-lived MCS, or a significant SBL disturbance. "Null" events will occur; they will not be targeted, but have some value in understanding essential ingredients. Nocturnal CI events appear to be sufficiently common, at least in the IHOP domain which included much of Kansas (Wilson and Roberts 2006). The same applies to bore-like features: Parsons et al. (2012) document 15 events in June alone within the IHOP domain. In short, the climatology suggests >10 bores and >10 CI events within the PECAN domain between 6/1 and 7/15 in a typical year.

The NSSL MCS climatology suggests that in a typical year the centroid of about 6 large MCSs in various stages of their lifespan should pass within 350 km from the PECAN mobile teams' headquarters (Hays, Kansas) in July and about 4-5 in June. This implies that ~7 targetable large MCSs would be expected within the nominal PECAN domain between 6/1 and 7/15 in a typical year. This number increases to ~9 if a smaller, less conservative radius of influence is used in the Gaussian KDE procedure (Fig. 1.3.3). The maximum straight-line distance that the mobile crews can deploy for an IOP is about 350 km. As mentioned before, the NSSL MCS climatology is biased towards large, long-lived MCSs while PECAN will also target smaller MCSs, which are far more common. The less restrictive 2-year objective reflectivity-based MCS climatology (Fig. 1.3.5.) suggests that about 10 nocturnal MCSs pass over Hays over a 45 day period sometime in JJA, and many more within a 350 km radius. Finally, the reflectivity-cell climatology suggests at least 24 nocturnal heavy precipitation (>50 dBZ) events over the 45 day period within the approximate PECAN domain (Fig. 1.3.2). The climatology thus suggests that a 45 day field phase is adequate to target at least 10 nocturnal MCSs. This number may be smaller than the number of bores or CI events, but MCSs are more long-lived and targetable. In summary, *the cumulative climatological evidence supports the feasibility of the proposed 10/5/5 IOP distribution (MCS/CI/bores) within the proposed 45-day period.*

1.3 Climatology

This section examines climatological analyses (a) to establish the existence and significance of nocturnal organized convection and related phenomena in the Great Plains, (b) to refine the location and seasonal timing of PECAN and (c) to determine the field phase duration that will likely suffice to sample enough "events", their diversity, and their significance. Three types of "events" are relevant to PECAN: elevated CI events; MCSs; and mesoscale disturbances, such as internal gravity waves, density currents, undular bores and solitary waves, that propagate on a SBL. Specifically, this section evaluates the seasonal and diurnal climatology of convective precipitation, MCSs, the LLJ, CI and bores.

A. Climatology of nocturnal convective precipitation

A 10-year climatology of composite WSR-88D data, ignoring any mesoscale organization, shows that in the warm season nocturnal convective precipitation is most common in central and eastern Kansas, where heavy precipitation is encountered about 1% of the time at night (**Fig. 1.3.1**). The highest probabilities are encountered in June. The area of frequent nocturnal convection shifts slightly northward from May to August; the peak region shifts from SE to central Kansas from June to July (Fig. 1.3.1). The diurnal amplitude of convective precipitation is strongest in July in the central Great Plains (not shown).

Significant convection (as defined in the caption of **Fig. 1.3.2**) occurs on average every other night within the black box in Fig. 1.3.1. Substantial intra-seasonal (week-to-week) and more limited interannual (±35%) variability exist within this box (Fig. 1.3.2). Nocturnal heavy precipitation is most common in the month of June within the box in Fig. 1.3.1, but there is no statistically significant trend in the typical number of targetable heavy precipitation events between early June and late July (Fig. 1.3.2). Summertime synoptic patterns tend to persist for several days; thus, the preferred regions containing ingredients supportive of both isolated nocturnal storms and MCSs are expected to have some day-to-day persistence (e.g., Tuttle and Davis 2006).

B. Climatology of nocturnal Mesoscale Convective Systems

Summertime nocturnal MCSs occur almost exclusively in the Great Plains, with occasional occurrences in the Midwest and the southeastern states. A core objective of PECAN (Section 1.1) regards nocturnal MCSs and their interactions with the SBL and the NLLJ. SPC and NSSL staff have assembled climatological information on the location and timing of relatively large MCS events that span the past two decades and are primarily based on infrared satellite imagery (e.g., Anderson and Arritt 1998, 2001). This climatology is event-based, and all members are at least 100 km in major axis dimension, lasting at least 5 hours. We refer to this as the NSSL large, long-lived MCS climatology, or the NSSL MCS climatology for short. Note that in the mesoscale continuum, there will be significant numbers of slightly smaller scale and/or shorter lived MCSs of interest and targetable by PECAN. The 7 years with the best data in the NSSL MCS climatology are 1992, 1993, and 1997-2001. This period includes 154 nocturnal MCSs in June and 187 in July. Large, long-lived nocturnal MCSs tend to first appear in the western central Plains, reach their peak extent in central and eastern portions of Nebraska, Kansas, and Oklahoma within the downstream exit region of the monthly-mean NLLJ axis, and decay further east (**Fig. 1.3.3**).

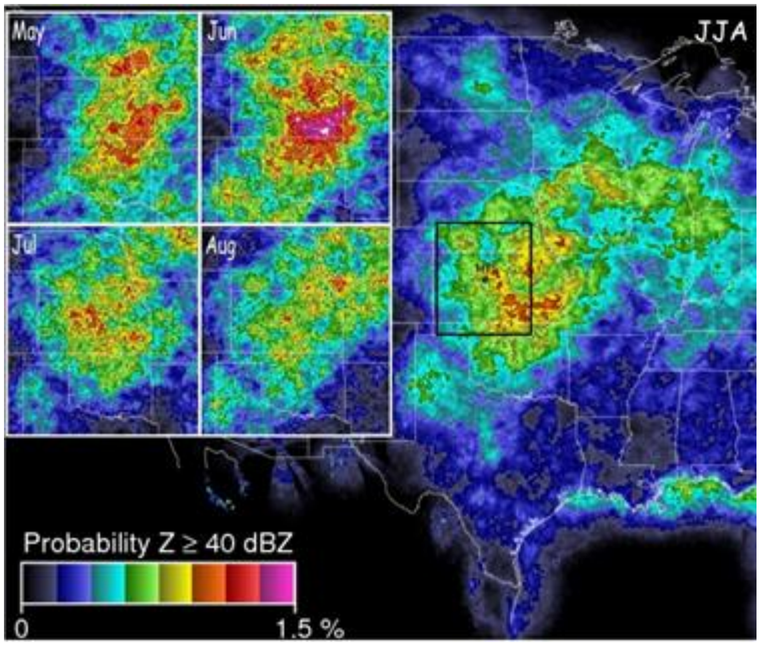


Fig. 1.3.1: Probability of radar reflectivity values exceeding 40 dBZ during the night, between 3:00 and 11:45 UTC, in the warm season (JJA), based on national WSR-88D composite 2x2 km^2 grid maps from 1996 to 2007 made every 15 min by WSI. The inset panels show the same, for the months of May to August. The black rectangle is a 5°x5° box centered on the proposed PECAN mobile operations center in Hays, Kansas (HYS). This box is very close to the nominal PECAN domain. (images courtesy Frederic Fabry – McGill University)

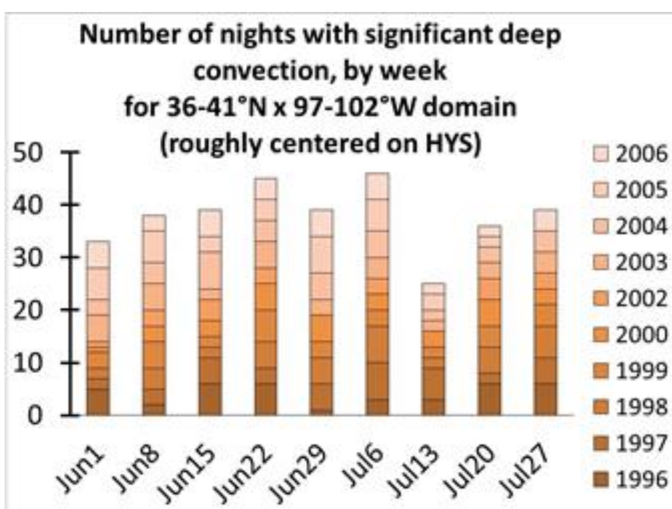


Fig. 1.3.2: Number of nights (0300-1200 UTC) per week that a radar reflectivity value of at least 50 dBZ was encountered in at least 2% (roughly 200 km^2, not necessarily a contiguous area) of the 5°x5° box centered on HYS (shown as a black box in Fig. 4.1) in June & July, based on 10 years of WSR-88D composite reflectivity data. The

count on the ordinate can be divided by 10 to obtain the #/week frequency in an average year. (analysis courtesy Matt Parker – NCSU)

Some seasonal northward progression of the MCS corridor is evident in Fig. 1.3.3: mature MCSs (i.e., the “max.” stage) are most frequent from Oklahoma through Iowa in June, but from Kansas through eastern Nebraska and central Minnesota in July. Large, long-lived nocturnal MCSs, irrespective of life stage, are most common in the Southern and Central Plains in May (not shown) and June (with up to 4 events per month), and in Nebraska in July (with about 6 events per month). A smaller, less conservative choice of radius of influence would produce peak values of 1-2 more systems per month in the Central Plains.

Interannual variability is significant, both for the season-total and for any particular month (**Fig. 1.3.4**). Note that Fig. 1.3.4 refers to the PECAN domain, which is a small part of the Great Plains region, and thus, given the small sample size, one can expect greater variability within a single month. June and July are the peak months for large, long-lived MCS frequency. The geographical extent of nocturnal MCSs also varies from year to year. In 2010 they were unusually frequent in the Midwest, from Iowa to Indiana and Minnesota (**Fig. 1.3.5**, referring to an objective reflectivity-based definition of an MCS). In 2011 Texas and Oklahoma were remarkably devoid of nocturnal MCSs, consistent with the extreme drought there. In both years MCSs were quite frequent in Kansas and southeastern Nebraska, with approximately one large, long-lived MCS within reach of the PECAN ground-based mobile crews every 3rd night.

C. Climatology of the LLJ, convection initiation, and bores

i. ***LLJ***

While the diurnal cycle of the Great Plains LLJ is well established (Bonner 1968), aspects of the nocturnal NLLJ dynamics, turbulence structure, and spatial and temporal heterogeneity, first documented by NSSP Staff (1963) and Hoecker (1963, 1965), remain poorly understood. A LLJ occurs as often as once every 3 nights during June and July as far north as southern Nebraska (Fig. 1.3.3). A LLJ was present within proximity of a mature-stage nocturnal MCS within or near the PECAN domain on roughly 60% of nights in June-July, according to the NSSL MCS climatology. This suggests that the NLLJ ought to be a rather ubiquitous feature within the PECAN domain (more common than MCSs.) The LLJ often dramatically weakens in the vicinity of large MCSs and this northern extremity may vacillate slightly in latitude over periods of 5-8 days (Tuttle and Davis 2006). In some cases the LLJ becomes elevated and decelerates as it crosses north of a baroclinic zone. This elevated, northern end of the LLJ can subsequently serve as a focus for the triggering of elevated convection, as well as provide a favorable mesoscale environment for MCSs initiated farther west and propagating on the north side of the surface boundary (Trier et al. 2006). Convection initiation aided by a frontogenetic circulation and MCSs traveling along the cold side of a surface front represent suitable PECAN targets, since the convection is more likely to be elevated, because the low-level CAPE-free stable layer typically is deeper and less penetrable than a fair-weather SBL.

ii. ***Convection initiation***

Convection initiation (CI) refers to the initiation stage of deep, precipitating convection. Isolated deep convection typically first develops in the late afternoon in a deep, well-mixed BL over the western High Plains or even the Rocky Mountains. Daytime CI over a low-level boundary often occurs in a line (e.g., Wakimoto and Murphey 2010, and numerous other IHOP studies), and the outbreak may evolve into a long-lived MCS (e.g., Marsham et al. 2011), as is the case for most MCSs in the NSSL MCS climatology (Fig. 1.3.3). Yet *CI also occurs locally in the Great Plains at night* (e.g., Billings and Parker 2012; Carbone et al. 2002). In some cases this convection remains fully elevated (i.e. the resulting convective updrafts and downdrafts are decoupled from the surface.)

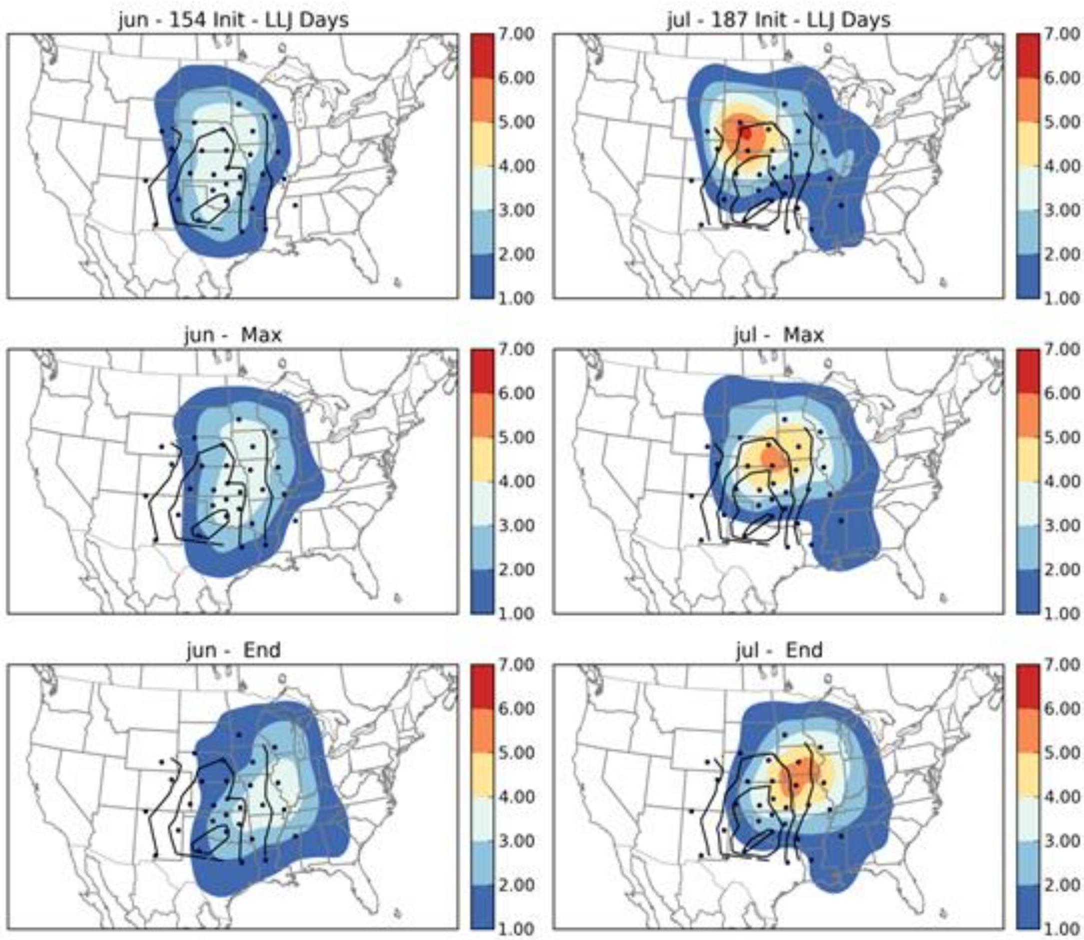


Fig. 1.3.3: Spatial distribution of large, long-lived MCSs at the time of MCS initiation (top), maximum extent (middle), and decay (bottom) in June (left) and July (right), as derived from the "NSSL MCS climatology" combining Gaussian kernel density estimation (KDE) and MCS-centroid locations (see text for details). MCS centroids at indicated stages were estimated from the -52°C IR cloud shield area. Shown is the number of systems per month whose centroid is within a radius-of-influence of 350 km, i.e. the maximum driving distance for the PECAN mobile armada (Section 4.3.A). Only systems whose "max" stage fell within 03 - 12 UTC are included. Also shown, in black contours, is the number of days per month (any day, not just the MCS days) with a LLJ during at least 4 hours between 03-12 UTC, using data from 1992-2005. The contours are smooth because the NOAA profiler network is sparse. The contours start at 4 days/month and are incremented at 4 day intervals. (Analyses courtesy of J. Correia-SPC, P. Marsh-OU and M. Coniglio and C. Ziegler of NSSL).

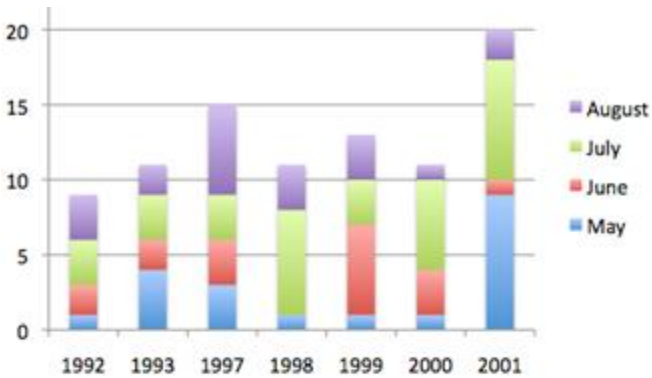


Fig. 1.3.4: The number of MCSs crossing the nominal PECAN domain (corresponding roughly to the 5°x5° box in Fig. 1.3.1) in the 7 years of the NSSL MCS climatology. Only systems with more than 150 km of track length and with a maximum-extent stage occurring in the period 03 - 12 UTC are included. (Analysis courtesy of Conrad Ziegler and colleagues at NSSL)

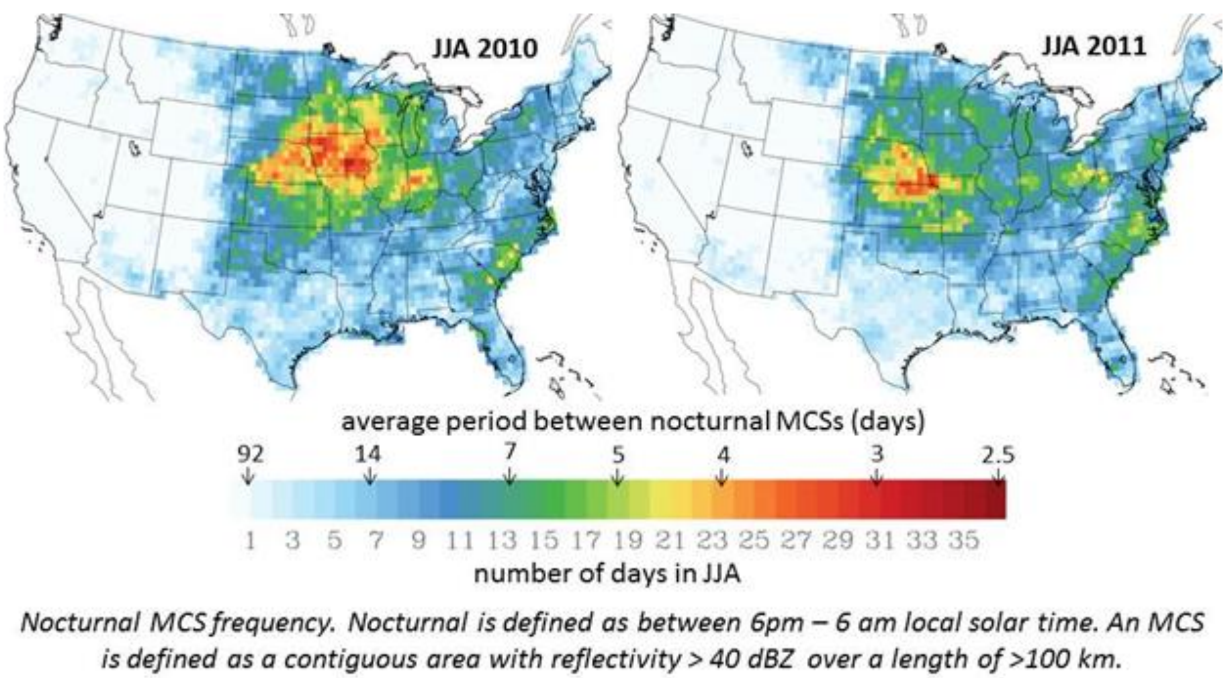


Fig. 1.3.5: Frequency of nocturnal MCSs on a 0.5°x0.5° grid in JJA 2010 and JJA 2011, based on the WSR-88D national composites. (Analysis courtesy of James Pinto - NCAR)

The climatology of elevated nocturnal CI is not known, but some insights have been gained from the IHOP campaign, conducted from mid-May to late June 2002 (Weckwerth et al. 2004). Wilson and Roberts (2006) report that about half of all CI events in the IHOP region (centered in western Oklahoma) were elevated. This fraction goes up to 80% at night (01-13 UTC). Most of the elevated CI cases were associated with elevated mesoscale convergence zones that were remote from any fronts and without any radar-detectable bores (Wilson and Roberts 2006). Experience gained during the NSSL-SPC Hazardous

Weather Testbed exercise in May-June 2011 suggests that these elevated convergence zones can be captured in mesoscale models. This fact, plus the findings in Wilson and Roberts (2006) and the overall frequency of nocturnal convection in the PECAN domain (Fig 1.3.1), suggests that CI will be both regular and targetable during PECAN, enabling new insights into the mesoscale ingredients and dynamics of elevated CI.

iii. ***Bores***

The frequency and diversity of undular bores in the Great Plains is poorly documented, and it is one of PECAN's objectives to improve on this. Bores and their impact on CI have been studied through chance encounters (e.g., Koch and Clark 1999; Koch et al. 2008; Marsham et al. 2011; Coleman and Knupp 2011), as vertical-structure information is lacking. Wilson and Roberts (2006) report 20 radar-detectable bores in the IHOP region, of which 3 resulted in CI. Parsons et al. (2013) used radar, profiler and surface data to document bores or bore-like features on 15 days with an additional 4 days of wave-like activity during the 45-day IHOP campaign (**Fig. 1.3.6**), mostly in western Kansas. These features tended to be generated early in the night most commonly at a gust front, and tended to decay in the second half of the night. Bores were detected over a typical length of ~150 km; one event was ~450 km in length. Undular bores and associated solitary waves are believed to be more common and of higher amplitude in the western part of the Great Plains, while nocturnal convection and MCSs are more common further east (Figs. 1.3.1, 1.3.3, 1.3.5). The reason is that the SBL tends to develop earlier in the evening hours and grow deeper in the western Plains where nighttime cooling is enhanced under cloud-free skies and in drier air.

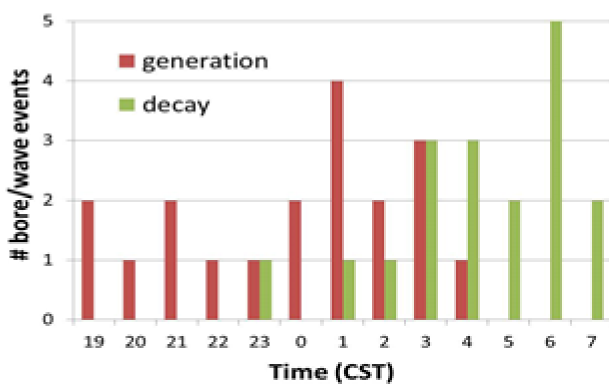


Fig. 1.3.6: Diurnal pattern of bore generation and decay based on S-Pol and WSR-88D data in the IHOP (13 May – 30 June 2002) domain, which includes western Kansas and Oklahoma, and the Texas Panhandle. The events earliest in the diurnal cycle had characteristics similar to those predicted by Liu and Moncrieff (2000) and thus were difficult to distinguish from density currents. (image courtesy of Dave Parsons - OU)

1.4 Instrumentation Overview

A. Profiling systems

i. ***PECAN Integrated Sounding Array (PISA)***

Concept. Essential to PECAN is the PECAN Integrated Sounding Array (PISA), a network of 10 units profiling the kinematic, thermodynamic, and moisture structure of the troposphere, mainly in the lower troposphere. The key goals of the PISAs, generally in concert with airborne and surface measurements, are to describe:

1. The evolution of static stability, low-level humidity, CIN, and most-unstable CAPE, in order 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, in order to quantify moisture transport, mesoscale convergence, and NLLJ-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.

The PISAs will also serve as a testbed for the nationwide network of profiling systems, as advocated in the 2009 National Research Council report "*Observing Weather and Climate from the Ground Up*". The NRC report calls for a characteristic spacing between profiling systems of ~125 km. The 6 PISA units that remain at fixed sites will have a spacing of ~200 km, but a higher density will be obtained through 4 mobile PISA units near anticipated CI and near MCSs.

PISA design. Four PISA units are designed as mobile units (MP), operating during IOPs, and 6 as fixed ones (FP), operating continuously. Partial mobility allows a telescoping spatial array with targetable density variations. Most MPs are entirely contained in vehicles and thus quite mobile, but all MPs will be moved between IOPs only, and remain stationary during IOPs. No two PISA units are the same. Some PISA units will capture the low-level wind field better than others. A few will capture the near-surface thermodynamic profile at very fine resolution, which is particularly important to describe the structure of transient, propagating SBL disturbances. Each PISA unit will have the following common measurement capabilities:

I. *Surface meteorological conditions:* basic meteorology at 1 min time resolution or better, but no eddy correlation flux measurements

II. *Upper air in situ data*: a radiosonde unit, for calibration purposes and comprehensive all-weather high-vertical resolution data. In two PISA units this is complemented by a tethersonde for more frequent profiling of the lowest 100 m, possibly up to 1000 m under weak winds.

III. *Remotely sensed wind data*, ideally but not necessarily in 3D (*u*,*v*,*w*). Low-frequency (400-915 MHz) wind profilers (WP) are all-weather capable, but have a poor time & height resolution. A Doppler lidar has a superb resolution but is limited to clear air. Thus radar and lidar systems are complementary. Also useful is a Doppler sodar to describe low-level winds at a range poorly covered by WPs and Doppler lidars.

IV. *Remotely sensed thermodynamic and humidity data*: A profiling multi-channel temperature/ humidity microwave radiometer (MR) has poor vertical resolution, but is not affected by clouds. The Atmospheric Emitted Radiance Interferometer (AERI) systems used in PECAN yield 2-3 times better resolution, especially in the mid-troposphere, but are clear-air-limited. Raman lidars measure water vapor mixing ratio; some also measure temperature using rotational Raman scattering. Raman lidars and water vapor Differential Absorption Lidars (DIALs) have excellent resolution in clear air up to cloud base. Thus MRs, AERIs and lidars are complementary, and therefore PISA units may carry one of each. Doppler and incoherent backscatter lidars are also useful, as aerosol layers often represent isentropic layers. In fact, because these simple aerosol systems have high time & vertical resolution, and can operate continuously with little attention, they are important in building a climatology of transient wave systems throughout PECAN.

The 10 proposed PISA units are summarized in Section 8. A map of the fixed PISAs is shown in Fig. 8.1.1. All units are currently in operation or deployment-ready. Most units involve multiple sources.

Fixed units. The DOE ARM CART Central Facility (CF) serves as an anchor in the SE corner of the PECAN domain (**FP1**). It is continuously operational and is surrounded by a small network of X- and C-band radars, however the X-band radars might not be fixed by June 2015 (Section 1.4.B below). The Howard University PISA (**FP2**) includes the powerful ALVICE Raman lidar (NASA/GSFC), measuring humidity, temperature, and aerosol backscatter, and GLOW (a NASA/GSFC Doppler Wind lidar), upper air sounding systems, an MR, as well as a tethersonde that has been used to ~1000 m AGL, measuring the turbulence structure function (CT^2) and energy dissipation rate in addition to standard meteorological variables. All components of FP2 have been field-tested. Unit **FP3** (ISS-449) features a high-frequency (~30 s) 7-panel phased-array 449 MHz WP currently under development at NCAR EOL. The 3-panel version has been tested and the full version should be tested and ready before the field phase. Also under development at NCAR EOL in collaboration with Montana State University is a low-cost, low-power water vapor DIAL. The low power requires a rather low temporal resolution (15 min) but is still adequate to capture bores. A WV-DIAL will be placed at FP3 with a DOE WV-DIAL at FP2. FP3 will also have the ARM AERI, a MR, a tethersonde, DL, backscatter lidar, sodar, and a radiosonde unit. Fixed PISA units **FP4** and **FP5** are Integrated Sounding Systems (ISS). They include a 915 MHz WP, a GPS radiosonde system (GAUS), a weather station, a sodar (at FP5 only), a wind lidar (at FP4 only), and a MR (at FP4 only) on lease from Radiometrics Inc. ARM AERIs will be available at FP4 and FP5 too. Finally, **FP6** consists of a MR, Doppler lidar, DOE radiosonde unit and surface meteorology. Under persistently anomalous weather patterns we may consider moving some FP units.

Mobile units. The mobile PISA units, as well as the mobile radars, will be deployed to any of a set of pre-selected sites within the target domain in the evening before an IOP commences and will remain stationary during the IOP. The confinement of MPs to single, select sites during any IOP will maximize data quality and quantity, integration with the fixed array, data assimilation value, and safety in a nighttime deployment. The truck-mounted **MP1** unit is the CLAMPS (Collaborative Lower Atmospheric Mobile Profiling System), consisting of a Doppler lidar measuring the horizontal winds in the boundary layer up to cloud base, a MR, and an infrared spectrometer (AERI system). This system is described in the one-page statement by Turner et al.(SPO, Section J). The Mobile Integrated Profiling System (MIPS) (**MP2**) includes a 915 MHz wind profiler, a 12-channel MR, a powerful X-band profiling radar, a Vaisala CL51 ceilometer, a 4 kHz sodar, a GPS radiosonde unit, and a weather station. These instruments are on a trailer pulled by an ambulance converted into a data coordination vehicle. Unit **MP3** includes the TWOLF (Truck-Mounted Wind-Observing Facility), a Coherent Technologies 2 μm, eye-safe, pulsed Doppler lidar, operating in RHI scanning or vertically-pointing mode. Mounted on the same truck is a high-resolution profiling FM-CW radar. The University of Wisconsin will also be providing SPARC for MP3 which has an AERI, multi-spectral aerosol lidar, DL, ceilometer, surface meteorology, and a radiosonde unit. The final mobile unit (**MP4**) is the NCAR EOL Mobile ISS (MISS).

ii**.** ***<u>Fixed and mobile ground-based radiosonde systems</u>***

Radiosonde units will be deployed as part of PISA (Table 1.4.1). NSSL will deploy two mobile sounding systems, both detached from the PISA, to fill potential gaps between mobile and fixed PISAs and operational sounding systems. Four radiosondes per day are routinely launched from the Central Facility (FP1). We obtained a grant from DOE for two supplemental soundings to be launched from the CF at night (at 3 & 9 UTC), and for five soundings a day from Larned KS, 3-hourly between 00-12 UTC. Also, the ARM proposal was accepted so FP6 will now have a radiosonde ground station and about 150 radiosondes (with balloons and helium.) To better capture variations in a larger region surrounding the PECAN domain, we made contacts to obtain additional soundings at 3, 6 and 9 UTC from the operational NWS radiosonde sites at KAMA, KOUN, KDDC, KTOP, KDNR, KLBF, and KOAX. The PECAN PIs will pursue NOAA funding for these additional NWS radiosonde sites, and cost will be kept low by using NOAA-trained REU students from local universities.

B. Radar systems

i. ***Mobile radars***

Several ground-based mobile radars will be used to observe bore disturbances and the NLLJ, obtain MCS-scale and storm-scale kinematic observations, and to estimate microphysical properties. The mobile radars will be deployed either upwind, ahead of the path of MCSs, or in regions with significant probability of elevated CI. PECAN will deploy a spatially extensive mobile radar array comprising radars that deploy once per evening and remain stationary as the target weather systems move and evolve within the array's coverage region. The mobile radars will be deployed in an array configuration that provides an optimal balance of areal and 3-D volume coverage, spatial resolution, near-ground coverage, and accuracy of synthesized multi-Doppler winds. Several of the mobile radars and/or their Scout/support vehicles will be equipped with mobile mesonet surface state instruments. The Operations Center in Hays, KS will have real-time access to select mobile radar data to facilitate IOP coordination. Due to intermittent availability, these real-time data will not be utilized as part of the radar mosaic display.

Bores and wave-like disturbances are often seen in S-band radar reflectivity (e.g., Kingsmill and Crook 2003; Wilson and Roberts 2006). The echo is attributed to Bragg scattering, although particle scattering cannot be excluded (Fulton et al. 1990; Knight and Miller 1998; Koch and Clark 1999). The mobile X-band radars may lack sensitivity to detect the Bragg scattering. Nocturnal clear-air X- and C-band echoes in Oklahoma in summer are largely due to insects (Martin and Shapiro 2007).

a. Storm surveillance Doppler capability

For the MCS and bore IOPs, wind analyses will be produced at a scale containing the central core region of the MCS and nearby cells (if present), with updates every 3-5 minutes. The CI IOPs similarly require wind analyses in the clear air, and later in a cluster or line of developing storm cells. Increased coverage will be accomplished via the forward-deployment of two mobile C-band Doppler radars (SMART-Radars) that are more sensitive to Bragg scattering, and more resistant to attenuation, resulting in a deeper penetrating capability through heavily-precipitating systems. The C-band

SMART-radars, one with dual-polarization capability, offer the needed coverage, beam width, and attenuation characteristics for MCS and storm surveillance. Coverage will be further increased by networking the C-bands radars with five X-band mobile radars (two dual-pol DOWs, the a single-polarization DOW, NOXP, and MAX). Radars will be arrayed in an approximate hexagon, with baselines of ~30 km, balancing potential radar interference, resolution, near-ground visibility, and areal coverage. A rapid-scan X-band mobile radar (RAXPOL) will be deployed in close proximity to MP3 (Table 1.4.1), in part to isolate insect biases.

b. Dual-polarization capability

Dual-polarization radar data are required primarily for two objectives. First, inferences about microphysical species and concentrations will be made for precipitation features in MCSs and isolated elevated storms. Second, dual-polarization data will be combined with observations from other radars at different wavelengths and the NOAA P3 *in situ* data to estimate the types, sizes and concentrations of precipitation particle scatterers, in part to evaluate the WSR-88D dual-pol particle ID algorithm. Several dual-polarization radars (NOXP, DOW6, DOW7, MAX, SMART-R1, PX-1000) will be utilized to augment the multiple-Doppler radar coverage of storm features while simultaneously obtaining polarimetric data.

ii. ***<u>Fixed radars</u>***

a. S-Pol

The NCAR S-Pol dual-polarization Doppler radar will perform two essential functions in PECAN. Firstly, it is the only S-band radar whose scan strategy can be controlled, in particular to conduct a series of vertical transects (RHIs) across clear-air SBL disturbances. Its clear-air detection capability, at any elevation, allows detection of bores and wave features (e.g., Wilson and Roberts 2006; Parsons et al. 2012). The RHI example on the EDO cover page (Browning et al. 2010) comes from the UK Chilbolton radar, which is very similar to S-Pol. S-Pol is also slightly more sensitive to clear-air Bragg scattering than the WSR-88D radars. (See Fig. 1.4.2. for S-Pol's location.) Secondly, the S-Pol dual-pol variables have long been used for particle identification (Vivekanandan 1999) and QPE (e.g., Brandes et al. 2001; Ryzhkov et al. 2002); its algorithms have been refined through experimental validation (e.g., Bringi et al. 2002; Brandes et al. 2003; Hubbert 2009). The WSR-88D radars recently have been augmented with dual-pol capability, yet their interconnected algorithms for melting layer detection, hydrometeor classification and QPE have hardly been tested with field data. S-Pol will provide collocated estimates using tested algorithms.

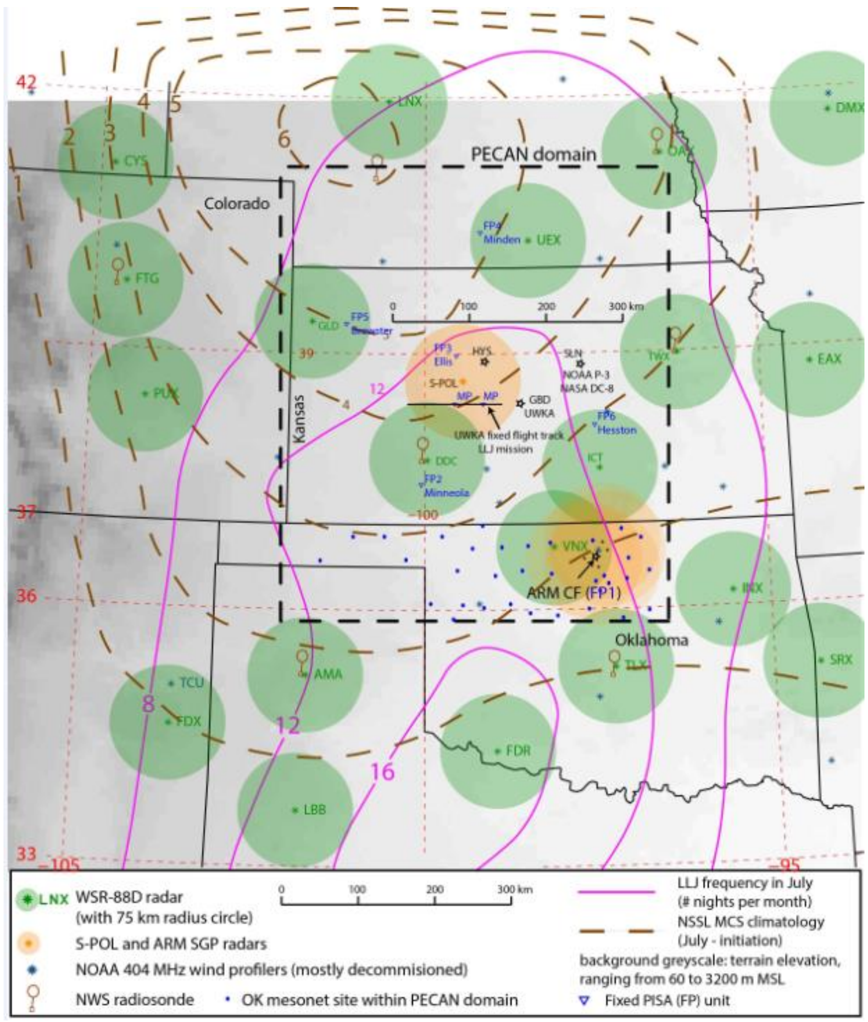


Fig. 1.4.2 Location of the PECAN domain (bold dashed line) in the Great Plains. Also shown are the operational networks (WSR-88D and ARM SGP), the fixed PECAN radar and PISA facilities, and climatological information (frequencies of NLLJ and of early-stage large MCSs, from Fig. 1.3.3). The radar range circles highlight the typical clear-air coverage. Clearly deep precipitation systems can be seen by operational radars anywhere in the PECAN domain.

The deployment of S-Pol has four additional benefits to those listed above:

1. It is unclear whether the vertical structure of nocturnal fine-lines (in an RHI) show isentropic vertical wave/bore displacements. Sharp humidity or temperature gradients subjected to turbulence can cause significant Bragg scatter due to fine-scale variations in refractive index (e.g. Davison et al. 2013). Bragg scatter patterns in a SBL disturbance should reveal material vertical displacements. The contrast in the return between S-Pol and the C- and X-band radars will aid in the interpretation of wave patterns. The clear-air radar signal at shorter wavelengths is likely dominated by insects (Bragg scatter 19 dBZ weaker for X-band than at S-band).
2. The data from the S-Pol will be utilized in the multiple-Doppler wind syntheses in combination with proximity ground-based mobile radar measurements.

3. S-Pol will provide low-level maps of radar refractivity in clear-air, which is a proxy for water vapor.
4. S-Pol will fill a gap in the WSR-88D coverage near Hays, KS (Fig. 1.4.2).

b. The WSR-88D network and the ARM SGP CF dual-polarized Doppler radars

Clearly the WSR-88D network of dual-pol S-band Doppler radars is essential to PECAN (Fig. 1.4.2). Less-known is the small network of fixed, dual-polarized C- and X-band Doppler radars (X-band scanning radars might not be fixed in time for PECAN) and a Ka/W band scanning cloud radar at the ARM SGP Central Facility. This dataset with fixed scanning strategies is freely available and may be viewable in CIDD/Jazz in the ops center. It will not be included in the PECAN radar mosaic. This network, which DOE plans to keep in operation until at least 2015, will be utilized to sample MCSs and bores in the southeastern sector of the PECAN domain. The data from the ARM CF radars will be utilized in combination with proximity mobile radar measurements in these cases, to conduct multiple-Doppler wind syntheses.

C. Aircraft

i. ***University of Wyoming King Air (NSF)***

The UWKA is a lower-tropospheric research aircraft with *in situ* probes measuring thermodynamics, kinematics, pressure, and turbulence. A humidity-only compact Raman lidar (Wang et al. 2011) will describe isentropic or aerosol layers below flight level, and the Wyoming Cloud Lidar will describe aerosol layers above flight level. At night the maximum range of the compact Raman lidar is ~1.0 km. Both the *in situ* and remote instruments are intended to capture the vertical structure of bores/waves along low-level flight legs. The UWKA will not penetrate MCSs, but it will detail the thermodynamics, kinematics and clouds of its inflow.

ii. ***DC-8 (NASA)***

The NASA DC-8 will fly mainly at about 8 km AGL. It will have the LASE (Lidar Atmospheric Sensing Experiment) Differential Absorption Lidar (DIAL) on board, to measure water vapor and aerosol layers below flight level. Comparisons of water vapor measurements with other sensors have shown the LASE water vapor mixing ratio measurements to have an accuracy of better than 6% or 0.01 g/kg, whichever is larger, across the troposphere (Browell et al. 1997). Plans are in progress for the DC-8 to also deploy the NASA Langley Research Center National Polar-orbiting Operational Environmental Satellite System (NPOESS) Atmospheric Sounding Testbed- Interferometer (NAST-I) Instrument. NAST-I is a Fourier Transform Spectrometer (FTS) providing spectrally continuous and high resolution (i.e., 0.25 cm-1) spectral radiances between 3.5 and 15 microns (660-2900 cm-1), thus yielding more than 9000 spectral channels of radiance information per spectrum. The upwelling spectral radiances are used to obtain temperature and water vapor profiles over a cross-track swath width of approximately 10 km when deployed on the DC-8. Approximate uncertainties and vertical resolutions are 1K/1 km for temperature, 15%/2 km for water vapor mixing ratio, and 15%/2 km for derived relative humidity.

The DC-8 will not fly into regions with active lightning and/or moderate/severe turbulence. Its flight tracks are designed to map the moisture field in advance of MCSs, prior to CI and in the bore environment in the clear air away from deep convection.

iii. ***WP-3D (NOAA)***

The NOAA P-3 aircraft carries a standard suite of cloud/precipitation particle probes, as well as thermodynamics, kinematics, pressure, and turbulence sensors. It carries a helically-scanning X-band tail Doppler radar with TA antennas pointing ~20° fore and aft of the fuselage, allowing either 3D pseudo-dual-Doppler or over-determined wind synthesis combining with the proximate ground-based radar radial velocities. The P-3 will fly a combination of straight legs and spiral vertical profiles in the trailing stratiform region of targeted MCSs. A dual-PRF (pulse repetition frequency) method is used to mitigate velocity ambiguities (Jorgensen et al. 2000).

D. Surface measurements

All PISA units will collect standard meteorological measurements at high-frequency (target: 5 s). The NSSL mobile sounding systems and the NOXP radar and both SMART-R scout vehicles will carry rooftop mesonet instrument racks (3 m AGL). The DOW group will deploy instrumented towers 10-18 m high at each of the three DOW radars, and 16 deployable Pod-mesonet units. In addition PECAN will deploy 6 mobile mesonet vehicles, 2 from NSSL and 4 from CSWR, that will be driving back and forth continuously along pre-selected roads that allow stopping when precipitation is heavy. This dense surface mesonet will be concentrated around the ground-based mobile radar array. 1 to 3 disdrometers will be deployed for surface drop-size distribution measurements in both fixed and mobile operation modes.

E. PECAN instruments and objectives matrix

All of the PECAN science objectives require multiple instruments and all benefit from the full PECAN instrument array. The instrument platforms and the science objectives to which they can contribute are listed in **Table 1.4.2**.

Table 1.4.2: Table of proposed PECAN research instruments and the science objectives they will address. All platforms will be deployed in the three mission types (CI, bores, and MCSs), except the NOAA P-3, which will participate in MCS missions only. Some instruments are intrinsically constrained to specific conditions, e.g. lidars are attenuated at the cloud edge. Some uncertainty remains about the shorter-wavelength radars to capture air motions and layer vertical displacements associated with SBL wave disturbances.

		CI	Bores	MCSs

PISA elements	ISS/MISS/ISS-449	X	X	X
	Radiosondes	X	X	X
	Microwave radiometers	X	X	X
	Wind lidars	X	X	X
	Water vapor lidars	X	X	X
	AERIs	X	X	X
	Tethersondes	X	X	X
	Tower observations	X	X	X
	MIPS	X	X	X
radars	S-Pol	X	X	X
	DOWs	X	X	X
	SMART-Rs	X	X	X
	RAXPOL	X	X	X
	NOXP	X	X	X
	FM-CW radar	X	X	X
	MAX	X	X	X
	Mobile mesonets	X	X	X
	Disdrometer(s)	X	X	X
aircraft	UWKA with WCL & RL	X	X	X
	NASA DC-8 with LASE & interferometer	X	X	X
	NOAA P-3 with tail radar			X

1.5 Funded projects

Table 1.5.1 details the funded proposals by PI name.

Table 1.5.1. Funded PECAN projects.

PI Name	Affiliation	Co-PIs	Proposal Title	Primary Instrument	Other instruments used
Richard Clark	Millersville	Todd Sikora	COLLABORATIVE RESEARCH: PECAN: Stable Boundary Layer Processes and Their Interaction with Nocturnal Convective Activities Over the Great Plains	PI-supplied (tethersonde, fluxes)	S-POL, DOWS, UWKA,ISS-incl. GAUS, ISS-449,mini-DIAL
Qing Wang	NPS		COLLABORATIVE RESEARCH: PECAN: Stable Boundary Layer Processes and Their Interaction with Nocturnal Convective Activities Over the Great Plains	PI-supplied (tethersonde, fluxes)	S-POL, DOWS, UWKA,ISS-incl. GAUS, ISS-449,mini-DIAL
Bart Geerts	UWyo	Zhien Wang, Tom Parish	Airborne measurements of the nocturnal low-level jet and wave disturbances in the stable boundary layer in PECAN	UWKA with lidars	SPOL, UWKA, ISS-incl. GAUS, ISS-449
Petra Klein	NSSL	Phil Chilson, Evgeni Fedorovich, Wayne Feltz, Alan Shapiro and David Turner	Low-level jets in the nocturnal stable boundary layer: their structure, evolution and interactions with mesoscale convergent zones	PI-supplied (CLAMPS and SPARC)	SPOL, UWKA, ISS-incl. GAUS, ISS-449, maybe mini-DIAL, MIPS
David Jorgensen	NOAA	Terry Schuur, Conrad Ziegler, Steven Koch	Microphysics and cold-pool dynamics of nocturnal MCSs	NOAA P-3 radar	SPOL, DOWS, UWKA, ISS-incl. GAUS, ISS-449, mini-DIAL, P-3
Greg McFarquh	UIUC	Bob Rauber,	Microphysical processes within stratiform regions of	NOAA P-3 radar &	SPOL, DOWS,ISS-

ar		Brian Jewett	deep nocturnal convective systems and their relationship to stable boundary layer dynamics	microphysics	incl. GAUS, ISS-449, mini-DIAL, P-3
Matthew Parker	NCSU		COLLABORATIVE RESEARCH: Measurement and analysis of nocturnal mesoscale convective systems and their stable boundary layer environment during PECAN	modelling, diversity of data	SPOL, DOWS, UWKA, ISS-incl. GAUS, ISS-449
Russell Schumacher	CSU		COLLABORATIVE RESEARCH: Measurement and analysis of nocturnal mesoscale convective systems and their stable boundary layer environment during PECAN	diversity of data	SPOL, DOWS, UWKA, ISS-incl. GAUS, ISS-449
Conrad Ziegler	NSSL/CIMMS/OU	Michael Biggerstaff, Michael Coniglio, Edward Mansell, and Terry Schuur	COLLABORATIVE RESEARCH: Measurement and analysis of nocturnal mesoscale convective systems and their stable boundary layer environment during PECAN	SMART-Rs, NOXP, mobile radars, mobile GAUS, mobile mesonets, NOAA P-3	SPOL, DOWS, UWKA, ISS-incl. GAUS, ISS-449, mini-DIAL
Michael Bell	U Hawaii Manoa		Convective and stratiform contributions to MCS longevity	NOAA P-3	SPOL, DOWS
Karen Kosiba	CSWR	Josh Wurman	Mechanisms for severe wind production in nocturnal and transitioning convection	DOWs, other mobile and stationary radars, MM, MS	SPOL, UWKA, ISS-incl. GAUS, ISS-449, maybe mini-DIAL
William Gallus	ISU		Forecasting nocturnal MCSs in PECAN	forecasting/ modelling	SPOL, DOWS, maybe UWKA, ISS-incl. GAUS, ISS-449
Stan Trier	NCAR		ARW-WRF Simulations of Thermodynamic Destabilization Supporting	modelling	

			MCSs in PECAN		
David Parsons	OU	Howie Bluestein	Investigating the Mechanism(s) for the Initiation and Maintenance of Nocturnal Convection Over the Great Plains; Clarifying the Role of Bores and other Wave-like Disturbances	diversity of data	SPOL, maybe UWKA, ISS-incl. GAUS, ISS-449, mini-DIAL
Belay Demoz	Howard	Bruce Gentry, E. Joseph, D. Whiteman, D. Venable	Ground Based Lidar Profiling of the Thermodynamic and Dynamic Structure of the SBL in PECAN	NASA lidars	SPOL, maybe DOWs, UWKA, ISS-incl. GAUS, ISS-449, mini-DIAL
Richard Ferrare	NASA	Amin Nehrir, John Hair	LASE Measurements during PECAN	LASE	UWKA, ISS-incl. GAUS, mini-DIAL
Tammy Weckwerth	NCAR	James W. Wilson, Rita D. Roberts	Studying Elevated Convection Initiation in PECAN	S-POL	SPOL, DOWs, UWKA, ISS-incl. GAUS, ISS-449, mini-DIAL
Kevin Knupp	UAH		Examination of vertical motion forcing within the afternoon	MIPS + MAX	SPOL, DOWs, UWKA, ISS-incl. GAUS, ISS-449, mini-DIAL
John Hanesiak	U Manitoba	Tammy Weckwerth	Nocturnal Boundary Layer/LLJ evolution and Elevated Convection Initiation	PI-supplied (MR, wind lidar)	SPOL, DOWs, UWKA, ISS-incl. GAUS, ISS-449, mini-DIAL
James Pinto	NCAR	Matthias Steiner, Joe Grim, Mei Xu	Object-based analysis of the short-term predictability of the macrophysical properties of nocturnal MCSs : Extending PECAN to other nocturnal CI regimes	modelling	UWKA, ISS-incl. GAUS, ISS-449, mini-DIAL
Xuguang Wang	OU	Dave Parsons,	Improving the understanding and predictive skills of	modelling	SPOL, maybe DOWs, ISS-

		Dave Stensrud	nocturnal convection duirng PECAN through advanced ensemble-based data assimilation and ensemble simulation		incl. GAUS, ISS-449, mini-DIAL

2. Planning and Schedule (Weckwerth/Geerts/Ziegler)

2.1 Staffing, Roles and Responsibilities

Staffing the Ops Center during IOPs

The following positions will constitute the operations center, located in a room at the FHSU campus in Hays. The people filling these positions should physically be in the same "situation room" in the Ops Center, rather than the field, if at all possible. Their responsibility is to follow the IOP evolution and communicate to their constituents, using xchat and cellphone. There will be no other coordination center (no Field Coordination Vehicle for example).

1. IOP Chair: in charge of the overall mission. This person typically is the representative science rep (MCS, CI, bore, LLJ …). The science rep may delegate to another person, so that the science rep can be in the field. The MST Chair serves as alternate choice.
2. Ops Director
3. MR coordinator
4. MP coordinator
5. MS + MM coordinator
6. Lead nowcaster
7. Asst nowcaster
8. UWKA coordinator
9. P-3 coordinator
10. DC-8 coordinator

The staffing roster for these positions can be found in the Appendix.

2.2 Daily Schedule

2.2.1 Daily Weather Briefing

2.2.2 Daily Planning Meeting

2.2.3 Pre-flight Aircraft Briefing

2.2.4 Weather Forecast Updates

2.2.5 Post-flight Aircraft Debriefing

2.2.6 Science Meetings

3. Decision Making (Rauber/Geerts/Weckwerth/Ziegler)

3.1 Regular Process

Process:

- The PECAN field phase is 1 June - 15 July, with the first possible IOP starting late on 1 June (2 June in UTC time) and the last possible IOP ending before dawn on 16 July (16 July in UTC time).
- Daily forecast discussions, open to all, will be held at 3 pm, starting Friday 29 May.
- Facility status updates must be made on the Field Catalog prior to the forecast discussion. The Ops Director will assume facilities/platforms are up and running unless otherwise marked on the Field Catalog.
- Proposals for any mission (MCS, CI, bore, LLJ) for the next night (Night 1) or the following night (Night 2) need to be prepared prior to the forecast discussion, such that they can be presented at the plenary meeting immediately following the forecast discussion. The Catalog Map tool should be used to display the proposed deployment of all mobile facilities.
- The Mission Selection Team (MST) will meet following the plenary meeting to decide on the proposal(s) for Night 1 (definitive plan) and Night 2 (tentative plan)
- The MST (look for the MST staffing roster in the Appendix) consists of:
    a. MST Chair: in charge of the overall mission
    b. Ops Director (Vidal Salazar or Jim Moore)
    c. UWKA flight scientist
    d. P-3 flight scientist (from 6/14 only)
    e. DC-8 flight scientist (from 6/28 only)
    f. MCS scientist
    g. CI scientist
    h. Bore scientist
    i. LLJ scientist
    j. Mobile radar coordinator
    k. Sounding coordinator

l. MP coordinator
m. S-POL + FP coordinator
n. Forecast Team Leader

Mission prioritization:

- The Facility Request and EDO call for 10 MCS missions, 5 bore missions, and 5 CI missions. These numbers will remain of central guidance in the MST's daily planning, as the field phase progresses.
- The MST is also aware that CI and bores are difficult to predict and relatively short-lived, so they do not need as high a level of forecast confidence as MCSs in order to call for a CI or bore IOP. In other words, missions are not decided solely on the highest forecast probability of occurrence.
- One of four mission types are selected for Night 1 (definitive plan) and Night 2 (tentative plan): MCS, CI, Bore, or (non-interfering) LLJ missions (see below). Each mission has its own deployment and sampling strategies and objectives. No mixed-objective or multiple-target missions will be called for. Yet targets of opportunity may arise during IOP progression, and thus some IOPs thus may be labelled mixed following the IOP (eg MCS + bore).
- Up to ~20 UWKA flight hours (~5 flights) will be dedicated to the LLJ along a fixed flight track. The LLJ IOPs (including associated MP operations near the track) have a lower priority because of the ubiquity, persistence, and predictability of the LLJ. Thus a LLJ mission will only take place if there is no competing mission on Night 1. A tentative LLJ mission on Night 2 may be scrubbed the next day if a core mission proposal is made.

MST Chair role:
The MST Chair is a facilitator and communicator first, not a rep for any given mission proposal. (S)he needs to put aside personal interest, and assist in representing the overall optimal result for the project.(S)he should be available for discussion prior to the daily forecast discussion, such that (s)he is aware of the likely mission proposals during the forecast discussion.
The MST Chair serves as the tie-breaker in the less-than-desirable event that the MCS, CI, and/or Bore proposals have an irreconcilable conflict. The MST Chair also moderates the discussion towards a speedy resolution, especially in cases where time is of essence.
In the event of an IOP following the daily MST meeting, the MST Chair will serve as IOP Director coordinating the overall IOP. The MST chair must be located in Hays.

3.2 Contingency Plans

3.2.1 Process allowing earlier deployment

3.2.2 Severe Weather at Salina

Salina is subject to stormy weather characteristic of the Great Plains during the study period. Salina weather will be forecast and nowcast to help assess whether currently deployed aircraft can return to base, whether to delay or abort planned flight operations, and whether to evacuate aircraft. Dealing with storms near Salina can range from delays in landing or takeoff to landing at alternate airports to temporarily moving the aircraft to other airports. The weather situations that could bear on such decisions can range from wind and rain to lightning, hail and tornadoes. The DC-8 and P-3 will be staged outside so that moderate winds and even small hail could require its evacuation. Evacuation decisions will come from consideration of NWS-issued weather watches and warnings as well as PECAN forecast/nowcast team assessments. If there is severe weather that precludes landing in Salina after research flight operations for a relatively short period of time, the aircraft could continue conducting scientific flight operations or simply loiter until a safe landing is possible. A list of potential alternate airports has been developed (Table 3.2.1). After such a diversion to an alternate airport, the aircraft will return directly to Salina without conducting science directed flights.

Table 3.2.1. Possible alternate airports if return to DC8 operations base is not possible. Airports near Salina are shown in the third column (in case of severe weather in Salina). Airports near the study areas are shown in the last four columns (in case of aircraft problems). Only civilian airports are listed. The distances in bold are closest to the city in the column header.

Airport	ICAO	Distance (nmi)				
		Salina	OK City	Lubbock	Greeley	Huntsville
Topeka Forbes Field	KFOE	**90**	**239**	444	426	507
Oklahoma City Will Rogers World	KOKC	**206**	0	**234**	450	537
Lincoln Airport	KLNK	**126**	329	500	362	601
Wichita Mid-Continent	KICT	**70**	**131**	**331**	379	548
Omaha Eppley Field	KOMA	**159**	363	536	402	594
Tulsa International	KTUL	**180**	**91**	**326**	484	468
Lubbock International	KLBB	377	**234**	0	428	761
Albuquerque International	KABQ	487	442	**252**	335	985
Cheyenne Regional	KCYS	415	484	479	**45**	945
Huntsville International	KHSV	584	537	761	925	0
Birmingham International	KBHM	617	546	757	957	**70**
Nashville International	KBNA	540	524	759	882	**84**
Memphis International	KMEM	428	369	596	766	**168**
Arkansas International	KBYH	234	**167**	408	561	**180**
Atlanta International	KATL	708	657	874	1051	**126**
Dallas-Ft. Worth International	KDFW	365	**156**	**259**	595	521
Rocky Mountain Metropolitan	KBJC	353	450	411	**34**	934
Denver International	KDEN	348	442	401	**34**	929
Colorado Springs Municipal	KCOS	335	403	346	**95**	907
Salina Municipal	KSLN	0	206	377	340	584

4. Operations Bases

4.1 Ops Center (Salazar)

Project Schedule

An overview of the PECAN schedule is shown in Fig 4.1.1. Note that the "Operation" periods vary somewhat for the different facilities. The overall operations period for PECAN is 1 June to 15 July 2015, several Intensive Operations Periods (IOP) will be declared by the Science Steering Committee. An IOP is better described in the mission selection planning section. IOP first day and second day scenarios will be usually declared 5 to 24 hours in advance of the start time. Project data sets are usually organized by IOP number.

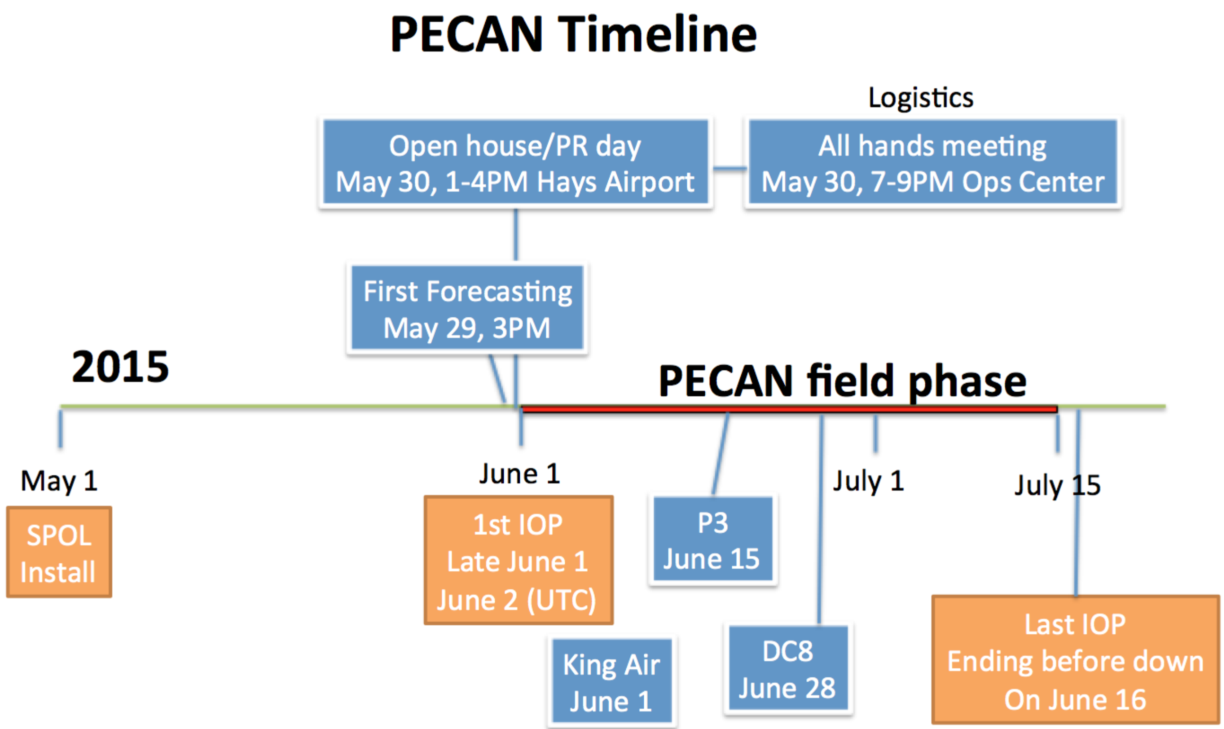


Figure 4.1.1 General overview schedule for PECAN Operations.

Initial operations for PECAN will begin with the setup and deployment of the SPol radar starting May 1, several mobile and ground based groups will begin the setup and deployment of their instrumentation around May 15, to be ready for operations on June 1st.

Some important dates for PECAN are as follow:

- May 29, 2015 – First forecasting meeting 3PM (details TBD)
- May 30, 2015 – Open house, Public Relations day. This event will take place at the Hays Regional airport from 1-4PM.
- May 30, 2015 – **All hands meeting**, 7-9PM at the Fort Hays State University Memorial Center, Black & Gold Room - Room 212.
- June 1, 2015 – First possible PECAN IOP.
- July 16, 2015 – Last possible IOP (ending before down on June 16).

The PECAN operations support will begin with the Field Catalog becoming operational (i.e. accept operational products) on 5/15, lasting through the project and approximately 2 weeks following the last IOP ~16 July. The operations center in Hays, KS will be set up between 5/27 and 5/29. It will be operational between 529 and 7/17, with teardown on 7/17. Numerical products and research model output related to PECAN operations should all be accessible on the Field Catalog by 6/1, lasting through 7/17.

The PECAN Operations Center will be located at the Fort Hays State University in Hays Kansas.

The PECAN Ops Center will be located at:

Please use this address for general deliveries to the Ops Center. For larger parcels, please contact the current site project manager.

Student Residential Life c/o PECAN Operations Center
Fort Hays State University
McMindes Hall #126
Hays, KS 67601

Please see figure 4.1.2 for a detailed map and an aerial view of the location of the PECAN Operations Center in the McMindes Hall of the Fort Hays State University.

Project Management support at the PECAN Ops Center

The PECAN Ops Center will be fully staffed by a Project Manager, Systems Administration support and Field Catalog support according to the following Schedule:

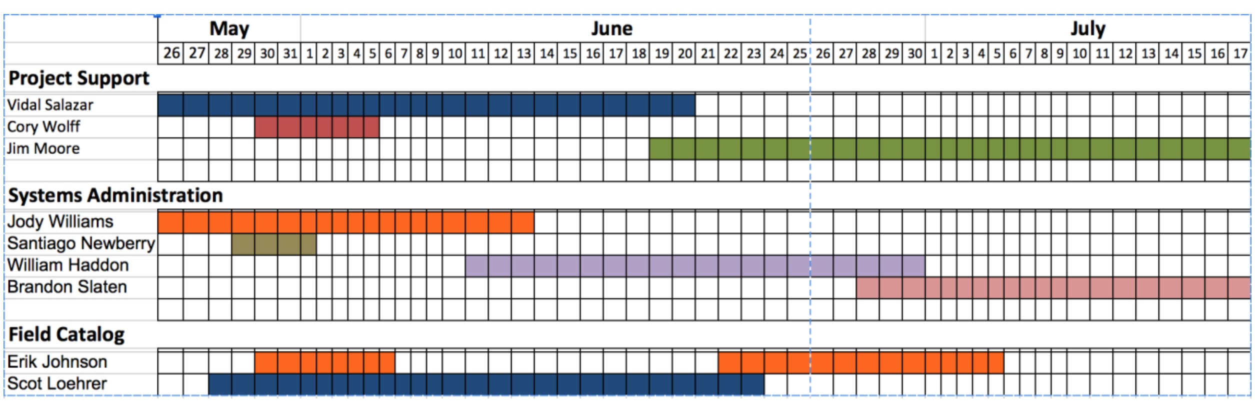


Figure 4.1.2 Aerial view of the location of the PECAN Operations Center.

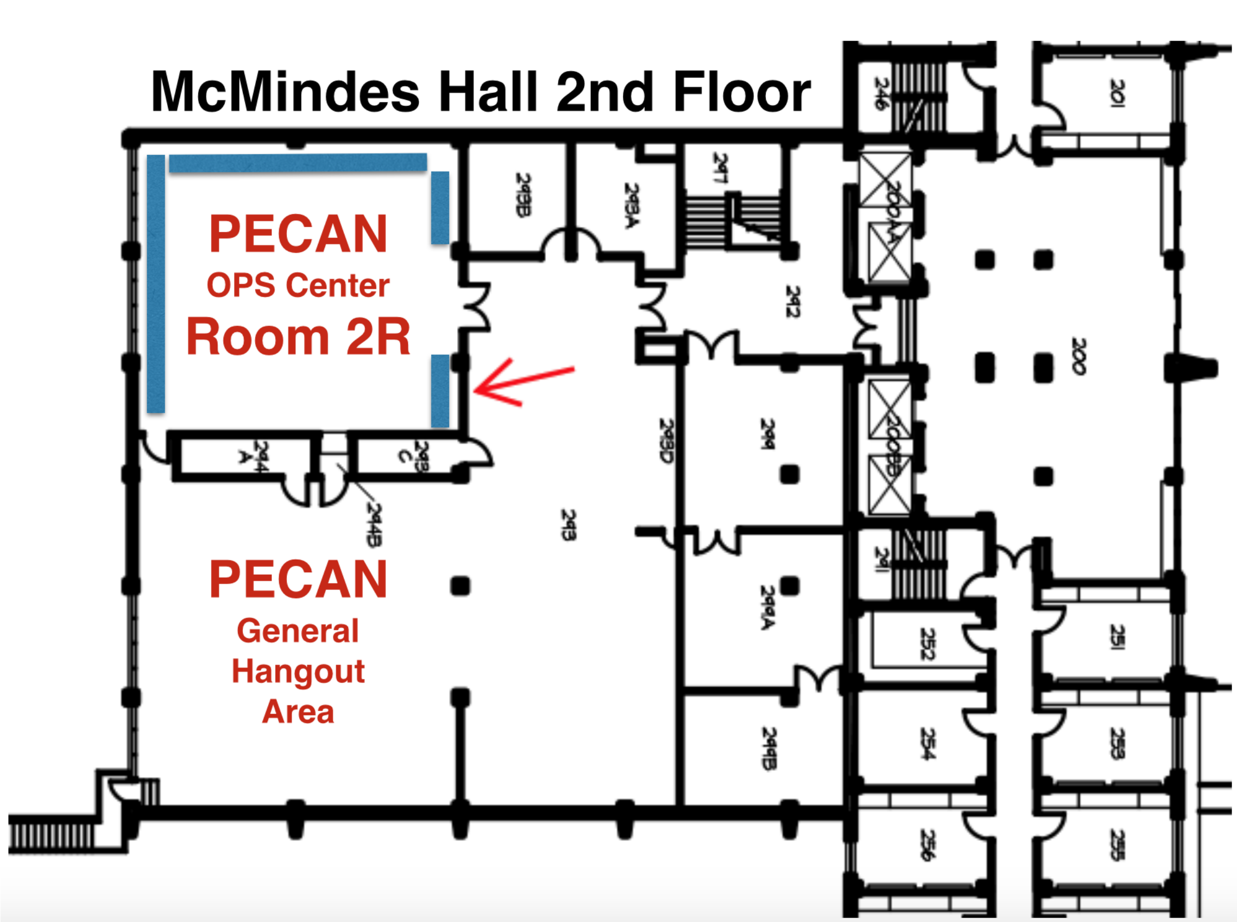


Figure 4.1.2 (Continuation) PECAN Operations Center.

Communications at the PECAN Ops Center

PECAN Ops Center local direct number:
Please call this number for general PECAN information.

XXX-XXX-XXX

Security at the PECAN Operations Center

All PECAN participants will be required to wear a PECAN badge for security reasons. The PECAN badge will be provided by EOL for all PECAN participants and will be handed out upon checking in at the Ops Center. Please register for the PECAN field campaign by providing your information in this website: https://www.eol.ucar.edu/content/registration-and-emergency-contact-information

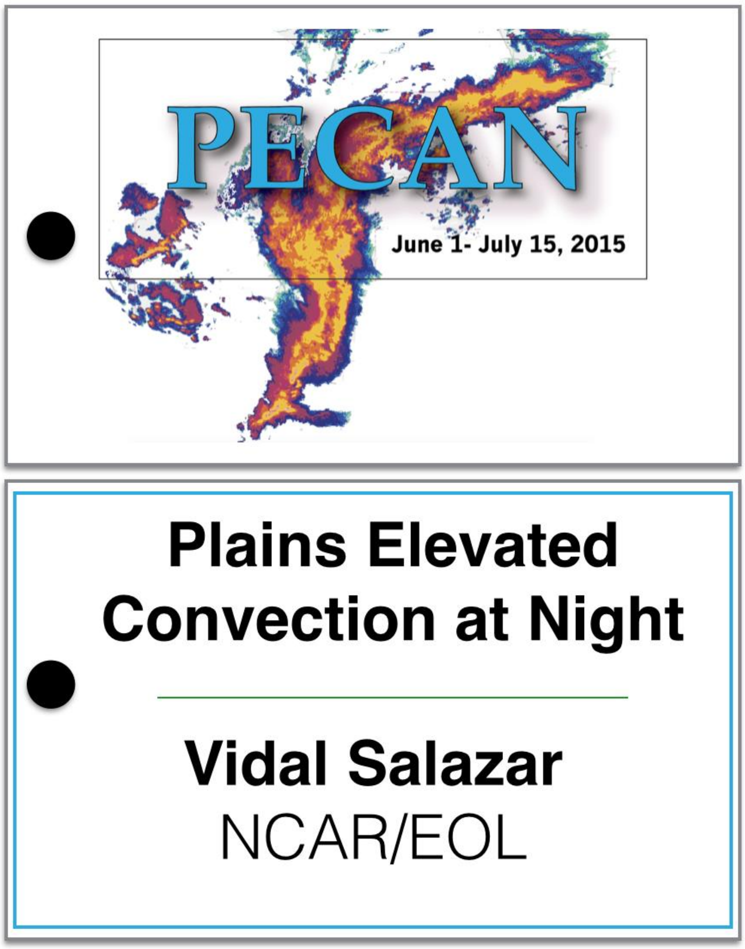


Figure 4.1.3 PECAN security badge

4.2 Salina layout for NOAA P-3 and NASA DC-8 (Jorgensen, Ziegler, Nehrir)

The airport in Salina, Kansas (Salina Municipal Airport) has been selected as the flight operations base for the NOAA P-3 and the NASA DC-8 aircraft during PECAN. A number of factors influenced this decision including the length and weight capacity characteristics of the runway, availability of hangar space for both aircraft if required, suitability of meeting space, familiarity with the facilities and facility capabilities from the DC-3 experiment, cost, and reduced average ferry time in the PECAN domain. The NOAA/Aircraft Operations Center (AOC) and NASA flight center facilities at Salina are described below in sections 4.2.1 and 4.2.2 respectively. Salina is located near the intersection of I-70 and I-135. It sits about 81 miles (90 miles driving) north of Wichita, Kansas, 164 miles (175 miles driving) west of Kansas City, and 400 miles (435 miles driving) east of Denver. Its population is about 47,700 (2010).

The Salina Municipal Airport (www.salinaairport.com) is operated by the Salina Airport Authority (SAA). Its main north-south runway (17/35) is 12,300 feet long capable of supporting 600,000 pound dual double tandem aircraft. There are also three smaller runways. The airport averages 166 operations per day (2010). There are two fixed base operators (FBOs): America Jet and Flower Aviation. The terminal sits near the southern end of the main runway.

The SAA has developed a document describing Rules and Regulations for the use of the Salina Municipal Airport (Appendix O): www.salinaairport.com/pdfs/FINAL%20%20SLN%20Rules%20and%20Regs.pdf. The document, also summarized in Appendix O describes activities that are allowed and those prohibited by users of the airport. Refer to the online version of the document for acronyms and definitions, and for any changes that may have occurred. Since Salina is an FAA secured airport, all personnel who will be accessing their respective aircraft on the flight line from the NOAA or NASA flight center buildings to must complete the airport operating area (AOA) training course.

4.2.1 Layout of Salina Airport facilities for NOAA P-3 (Jorgensen, Ziegler)

The P-3 will be located on the runway outside of the old FBO (Building 409) that AOC is leasing a portion of (Figure 4.2.1.1). Since it will be locked 24 hours a day, supervisors will have keys for access as needed. It has both wired and password-protected Wi-Fi high-speed Internet access and plenty of space for meetings and discussions. There is also a TV monitor to serve a computer display for PECAN operational briefings. Although AOC uses cell phones for communications, a landline phone with a speaker and a single line will be installed for voice briefings with the PECAN Operations Center via GoToMeetings. AOC and science staff will bring laptop computers. A laptop computer with stable high-speed Internet access and connected to the TV monitor must be able to handle video teleconferencing with the PECAN Operations Center via ReadyTalk.

For P-3 crew arriving Monday 15 June to begin the first phase, the AOA training course will be given that Monday afternoon (6/15) at 2 pm Central Standard Time at the firehouse located at the north end of the lower group of buildings (i.e., north of Hangar 600 in Figure 4.2.1.1). Additional training classes will be held as necessary so that all are covered. The first potential MCS mission day for the P-3 is Tuesday 16 June, while the last potential P-3 mission day is Monday 13 July. The P-3 will depart from Salina on 15 July.

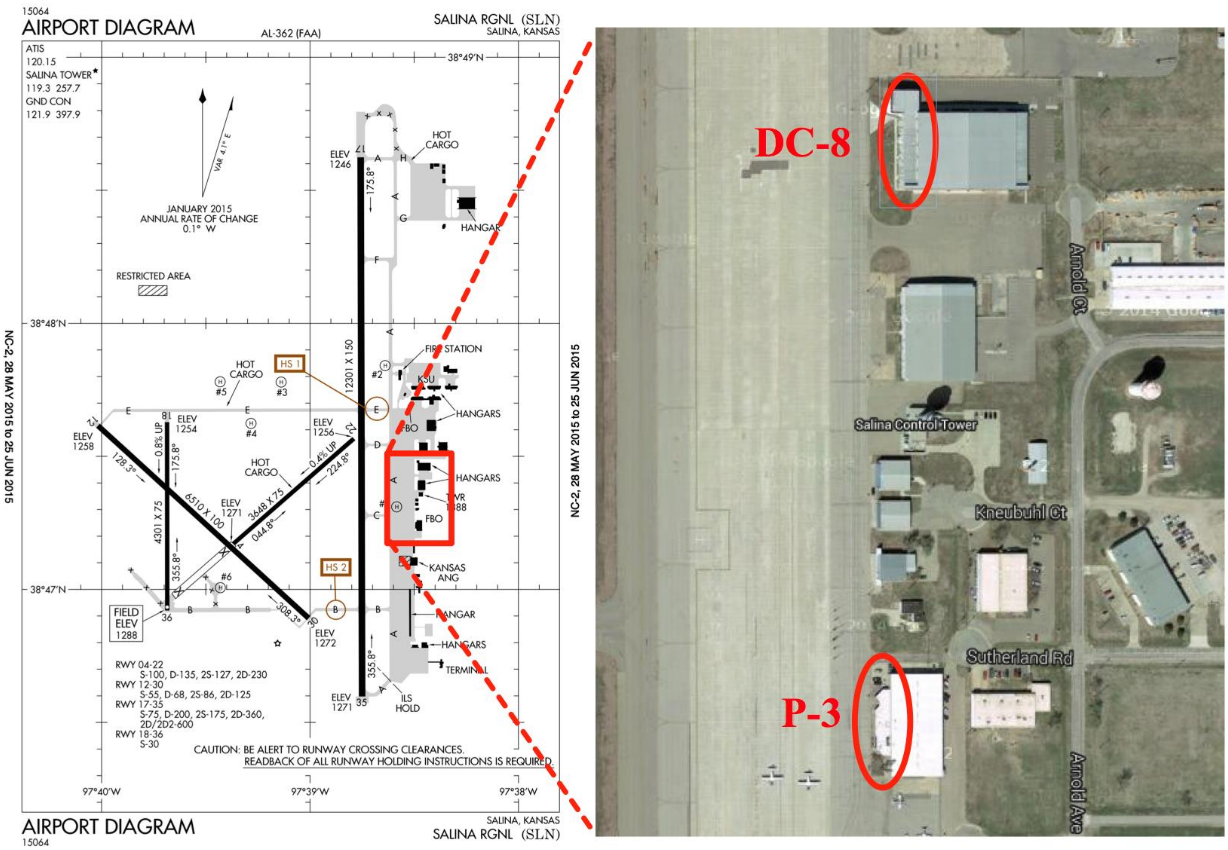


Figure 4.2.1.1. Location of NOAA and NASA flight centers at Salina Regional Airport for P-3 and DC-8 aircraft respectively. Left panel: airport grounds with inset flight centers area; right panel: inset showing red-circled P-3 and DC-8 locations. The P-3 is based at the FBO building (lower right) while the DC-8 is based at Hangar 600 (upper right). The “Fire Station” site of AOA training is north of the inset in the left panel.

4.2.2 Layout of Salina Airport facilities for NASA DC-8 (Nehrir)

The DC8 will be located on the runway outside of Hangar 600 (Figure 4.2.2.1). The DC-8 will utilize very little space of Hangar 600 during the project deployment period, requiring only space to store one conex box for aircraft components and several smaller boxes for research equipment. The entire hangar area totals 42,052 square feet. The hangar doors can accommodate 100 foot wingspans and 28 foot tails if required. We will also use the office space on the west side (~10,000 square feet) and the customer service center office space (6,300 square feet). The facility has wired (in the office space) and WiFi Internet service (throughout the hangar and office space). The NASA DC-8 crew and science team members will occupy the first floor office space of Hangar 600 (Figure 4.2.2.2). A notional floor plan for the office space is shown in Figure 4.2.2.2.

Figure 4.2.2.1. View of DC-8 outside of Hangar 600.

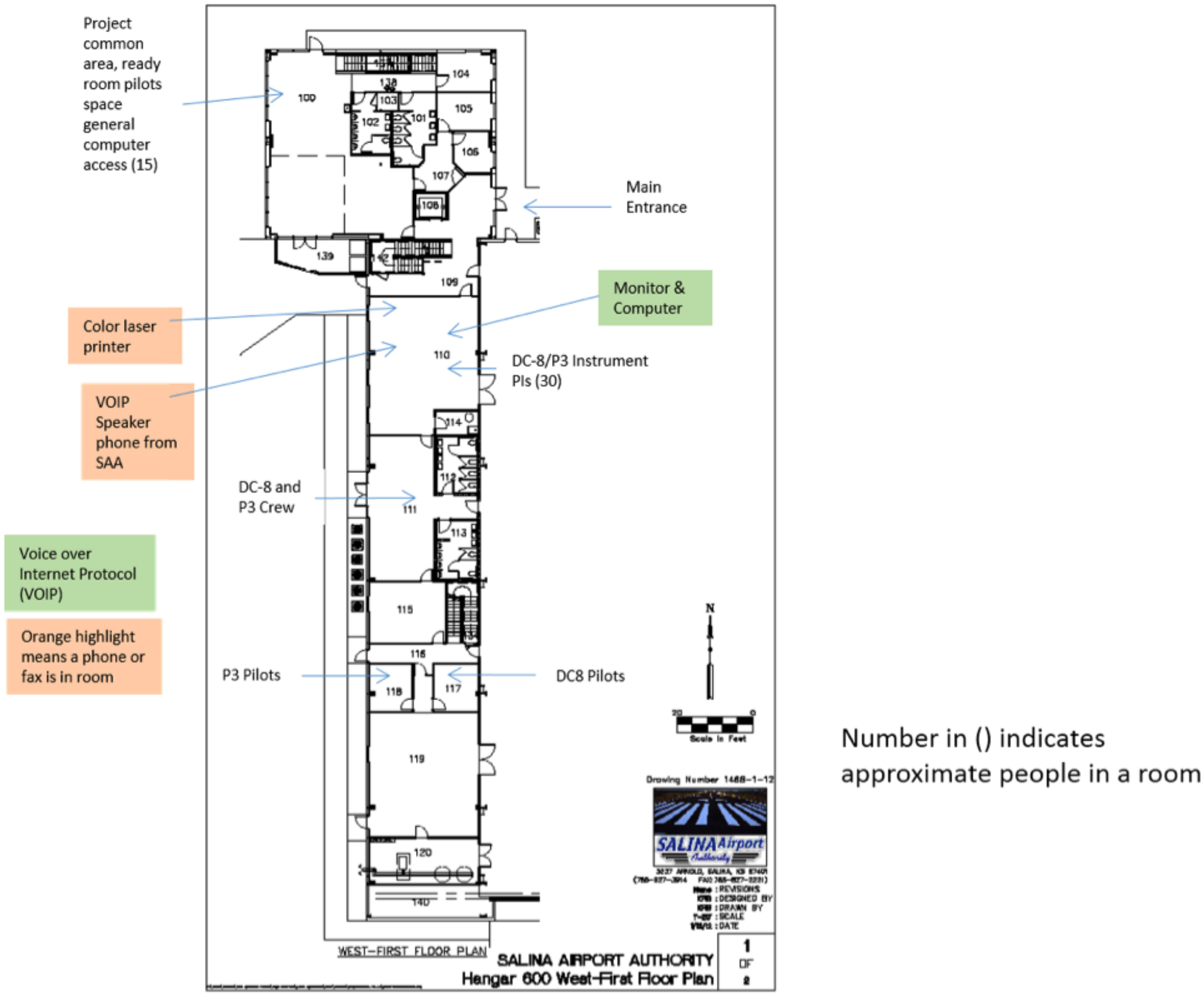


Figure 4.2.2.2. Notional office space floor plan. Note updated P-3 aircraft and crew location in Fig. 4.2.1.1.

4.3 Great Bend layout for UWKA (French)

5. Project Communications (Salazar)

5.1 Overview

PECAN project communications are important for the success of the field efforts. EOL will provide a series of tools that will be used by the PECAN participants to disseminate information related to the PECAN planning, IOP, asset location and general project communications.

The PECAN Operations center will have the following communication tools:

For Teleconferencing and overall meeting support

ReadyTalk.

- ReadyTalk
    - Available for all project participants
    - **To join a meeting, please call 1 866 740 1260 Access code is 497 8380 (this number will be valid throughout the PECAN deployment.**
    - To initiate a call or a teleconference, please see your Ops Center support manager for the access key.
    - For web presentations (when available) please go to www.readytalk.com and use the same access code (497 8380)
    - Please note that Readytalk uses the latest java plugins, please make sure your computer is up to date.
- A general PECAN presentation computer will be available at the Operations Center. This computer will have the latest Office products and MAC presentation tools as well as Adobe acrobat and Readytalk.

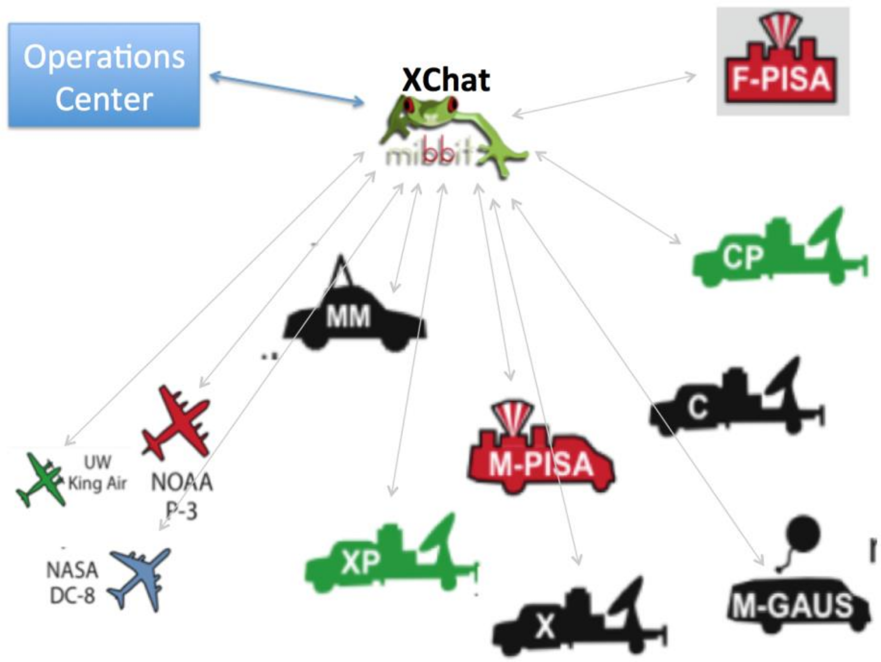
Operations Center Phone number

A local phone number for the PECAN Operations Center will be available for project communications. The number will be available May 29, 2015 and is:

XXXXXXXXXXXXXX

5.2 Situational awareness

Project communications for situation awareness will be crucial for the success of PECAN. Communications between the mobile and fixed assets will be possible via 2 main channels.



XChat communications

XChat communications will be possible between mobile and fixed assets using the interphase provided via the field catalog. To use XChat please use the portal link located in the field catalog (http://catalog.eol.ucar.edu/pecan)

Direct communication with the Ops Center via the planning tool.

The Field Catalog planning tool will be able to send SMS, Text and direct messages to all mobile and fixed assets for communication purposes. It is important to provide personal, emergency and asset information for the project so the communications are efficient and uninterrupted.
Please register for the PECAN campaing by entering your participation details here:
https://www.eol.ucar.edu/content/registration-and-emergency-contact-information
Your information will kept confidential and will be used to produce a communication list of all PECAN participants.

5.3 Communications hardware

GPS for mobile assets

EOL is planning to provide field catalog support for the upcoming PECAN campaign. Part of this support will include the ability to track mobile platforms associated with the project, both airborne and ground-based.

EOL has worked out a solution with DeLorme where we can get automatic reports of platform locations at intervals from 30 seconds to 10 minutes. The reports will be ingested into the Field Catalog in real-time during the campaign to show the latest position of each platform and to allow playback of platform locations from any date/time during the campaign. The Catalog Maps tool, a GIS-based tool will provide all users with this ability both during the campaign as well as in the months and years to follow.

In order for all of this to happen, each mobile vehicle that needs to be tracked will need to carry a DeLorme inReach GPS device : http://www.inreachdelorme.com/product-info/ . These devices (a DeLorme inReach SE or the DeLorme inReach Explorer) retail for between $299 - $379. Each device also requires a service plan. These plans can be set up for monthly or yearly service periods. Costs are based on the amount of data sent. The nice feature about these devices is that they both include the ability to send SMS text messages via satellite, so they are not subject to cell phone coverage areas.

Each team will need to purchase their own devices and pay for their own plans. During set-up you will be able to direct your real-time tracking info to a specific URL. This will allow us to gather your data in real-time and we'll have set-up instructions for you to help you through this.

EOL recommends:

1. Purchase an inReach SE ($299) or an inReach Explorer ($379) for each of your vehicles that will need to be tracked during PECAN. This should include all mobile radars, mesonets and mobile sounding teams. The CSWR team and the NSSL group have already purchased these for some of their vehicles.
2. Set up a monthly Enterprise plan (see attachments for more details). A plan we recommend is DeLorme 4, 12,000 bytes per device per month. Price = $42.20/month . We would recommend you turn this on at least 2 weeks prior to the start of PECAN so we can get everyone's data ingest set up and run it for a 2 month period. You can turn this off after PECAN to end the monthly charges.

For most vehicles we expect the maximum update rate would be 2 minute intervals. Many may be satisfied with 10 minute updates. This is configurable on your device with regard to how often you send tracking points. The more frequent you update, the more data that you'll use, so take this into account when you consider plans.

DC-8

The DC-8 has SatCom capabilities that allow voice and data exchange with both Salina aircraft base of operations as well as with Hays, the main PECAN base of operations. We anticipate transmitting LASE real-time images of water vapor and aerosol distributions to guide in the positioning of ground resources prior to and during IOPs.

5.4 Software planning tools

6. Aircraft Operations (French, Jorgensen, Ferrare)

6.1 Capabilities, Payloads, Constraints, Safety

6.1.1 University of Wyoming King Air (French)

xx

6.1.2 NOAA P-3 (Jorgensen)

NOAA WP-3D Aircraft Characteristics

The NOAA WP-3D aircraft (Fig. 6.1.1) is one of the two P-3 aircraft supported and deployed by the NOAA Aircraft Operations Center (AOC) in Tampa FL. These aircraft have led NOAA's continuing effort to monitor and study atmospheric and oceanic systems in support of atmospheric and oceanic forecast of environmental conditions as well as other NOAA missions. Table 1 gives the standard specifications of the NOAA WP-3D aircraft. The N43RF ("Missy Piggy") will be deployed for PECAN.

Figure 6.1.1. The NOAA WP-3D aircraft and location of instruments for general development. Information and figure obtained from http://www.aoc.noaa.gov/aircraft_lockheed.htm

Of particular interests to science mission planning are the maximum payload, flight duration, on station aircraft speed, maximum climb rate, and maximum altitude (ceiling). These properties are summarized in Table 6.1.1 for the NOAA WP-3D.

Table 6.1.1. Summary aircraft specifications relevant to mission planning. Information were obtained from http://www.aoc.noaa.gov/aircraft_lockheed.htm

	NOAA WP-3D
Endurance	9.5-11.5 hours
Range	2,225 nm (4,100 km) low altitude (<18,000 ft or 4.8 km) 3,300 nm (6,100km) high altitude (>18,000 ft or 4.8 km)
Ceiling	27,000' (8.2 km)
Aircraft ground speed	~120 ms^{-1}
Maximum rate of climb	3000 FPM
Scientific payload	9000 lb
Max. non-crewmember	11

Basic NOAA WP-3D Instrumentation

Each of the two NOAA WP-3D aircraft is equipped with a variety of scientific instrumentation, radars and recording systems for both *in-situ* and remote sensing measurements of the atmosphere, the earth, and its environment. Table 2 gives an overview of the standard instrumentation aboard the aircraft and a general description for each category.

Table. 6.1.2. Overview of the NOAA P-3 instrumentation. Information were obtained from http://www.aoc.noaa.gov/aircraft_lockheed.htm

Skywatch Collision Avoidance System (TCAS):	An airborne traffic advisory system that assists the flight crew in visual acquisition of aircraft that may pose a collision threat.
Altitude Alert System:	System that provides flight crew with visual and audio warnings about a variety of flight conditions regarding the altitude of the aircraft.
Flight Level *in situ* Sensors:	Navigational parameters Pressure, temperature, and water vapor Mean winds and turbulence Cloud physics Radiation
Radars:	Rockwell Collins C-band nose radar Lower fuselage C-band research radar – 360 deg. horizontal fan

	beam Tail X-band Doppler radar
Expendables:	GPS dropwindsonde atmospheric profiling system Airborne Expendable Bathythermographs (AXBTs) Airborne eXpendable Conductivity Temperature and Depth probes (AXCTDs)
Others:	C-band and Ku-band scatterometers Stepped Frequency Microwave Radiometer External Wing Store Station Mounts

The three essential instrument groups (flight level sensors, radars, and expendables) on the NOAA WP-3D are described in the following sections.

Flight level instrumentation

Table 6.1.3. lists all flight level measurements to be made on the WP-3D during PECAN. Instruments from individual research PI are listed with the PI institute name.

Table 6.1.3. NOAA WP-3D flight level data and instruments for PECAN.

Parameters	*Instruments*	*Fast/Slow*
Position	INE and GPS, Oxford RT3003 GPS/INS	S
Ground Speed Vector	INE and GPS, Oxford RT3003 GPS/INS	S
Aircraft Altitude	Radar and pressure altimeters	S
Attitude Angles (heading, pitch, and roll)	INE and GPS, Oxford RT3003 GPS/INS	F
Air Temperature	Deiced Rosemount total temperature (2) UCI Rosemount temperature UCI-Modified Rosemount dual-thermistor (2)	S F F
Humidity	Edge Tech Vigilant (2)	S

	UCI LI-COR 7200 (with CO_2) UCI-modified Krypton	F F
Static Pressure	Flush ports with Rosemount 1281AF pressure transducers	F
Dynamic Pressure	Flush ports with Rosemount 1221 F1AF pressure transducers	F
Flow Angles (sideslip and attack angles)	Rosemount 858 AJ 5-hole with Rosemount 1221F2VL transducers Radome gust system with Rosemount 1221F2VL transducers	F F
Small Cloud Droplet Spectrum	FSSP forward scattering probe	F
Cloud Droplet Spectrum	PMS 2-D Gray and/or mono probes	F
Hydrometeor Size Spectrum	PMS 2-D Gray and/or mono probes	F
Cloud Drop Size Distribution	UCSC Phase Doppler Interferometry (DPI)	F
Cloud liquid water/Total Liquid Water	SEA WCM-2000 Multi-Element Water Content System	F
Sea surface temperature	KT19.85 II	S
CO_2 air temperature	KT19.85 II	S
Shortwave Radiation	NRL-Modified Kipp & Zonen CM-22 pyranometers	S
Longwave Radiation	NRL-Modified Kipp & Zonen CG-4 pyrgeometers	S
Cloud structure; surface	Video photography (nose, side and vertical)	S

Airborne radars

Airborne Doppler Radar Scanning Methodology

The characteristics of the NOAA P-3 vertical-scanning Doppler radar are listed in Table 4. The Doppler radar is X-band and is restricted to a maximum antenna rotation rate of ~60° s^{-1} (~10 RPM). The system employ a multiple PRF (pulse repetition frequency) scheme to extend the radial velocity Nyquist interval to > 50 m s^{-1}, greatly easing the work required to dealias (or unfold) radial velocity data sets, which is required for proper determination of the 3-D wind fields.

Table 6.1.4. Radar parameters for the NOAA P-3 Doppler radar.

Parameter	***Description***
Scanning Method	Vertical about the aircraft's longitudinal axis; fore/aft alternate sweep methodology
Wavelength	3.22 cm (X-band)
Beamwidth:	
Horizontal	aft: 2.07°, fore: 2.04°
Vertical	aft: 2.10°, fore: 2.10°
Polarization (along sweep axis):	Linear horizontal
Sidelobes:	
Horizontal:	aft: -57.6 dB, fore: -55.6 dB
Vertical:	aft: -41.5 dB, fore: -41.8 dB
Gain:	aft: 34.85 dB, fore: 35.9 dB
Antenna Rotation Rate	Variable 0-60° s^{-1}

Fore/Aft Tilt:	aft: -19.48°, fore: 19.25°
Pulse Repetition Frequency	Variable, 1600 s^{-1} – 3200 s^{-1}
Dual PRF ratios	Variable: 3/2 and 4/3, typical
Pulses Averaged per Radial	Variable, 32 typical
Pulse Width	0.5 µsec, 0.375 µsec, 0.25 µsec
Rotational Sampling Rate	Variable, 1° typical
Peak Transmitted Power	60 kW
Unambiguous Range with Interlaced PRT technique	38-92 km
Unambiguous Radial Velocity with Interlaced PRT technique	13-71 m/s
Along track beam spacing	~1.4 km
Range resolution	150 m

Figure 1.6.2 illustrates the scanning methodology. The scanning strategy is to utilize the fore/aft scanning technique to sweep out a three-dimensional volume during the aircraft's flight track. Alternative sweeps are scanned forward then aft by about 20° from a plane that is normal to the aircraft's longitudinal axis. At intersection points of the fore and aft beams a horizontal wind estimate can be made. The horizontal data spacing of those intersection points depends on the antenna rotation rate and the ground speed of the aircraft. For typical values of ground speed the typical data spacing is ~1.4 km. For psuedo-dual-Doppler analysis that derives 3-D winds an assumption of stationarity of processes during the data gathering must be made. The time interval between any two intersecting beams is a function of the aircraft's ground speed and antenna scanning rate, and range from the aircraft. For the P-3, with a typical ground speed of ~120 m/s and the maximum antenna rotation rate of ~10 RMP, the typical time interval between beams is ~ 1 min per 10 km range from the aircraft. The maximum effective range of the radar is ~40 km, so the time period of assumed stationarity is ~ 4 minutes.

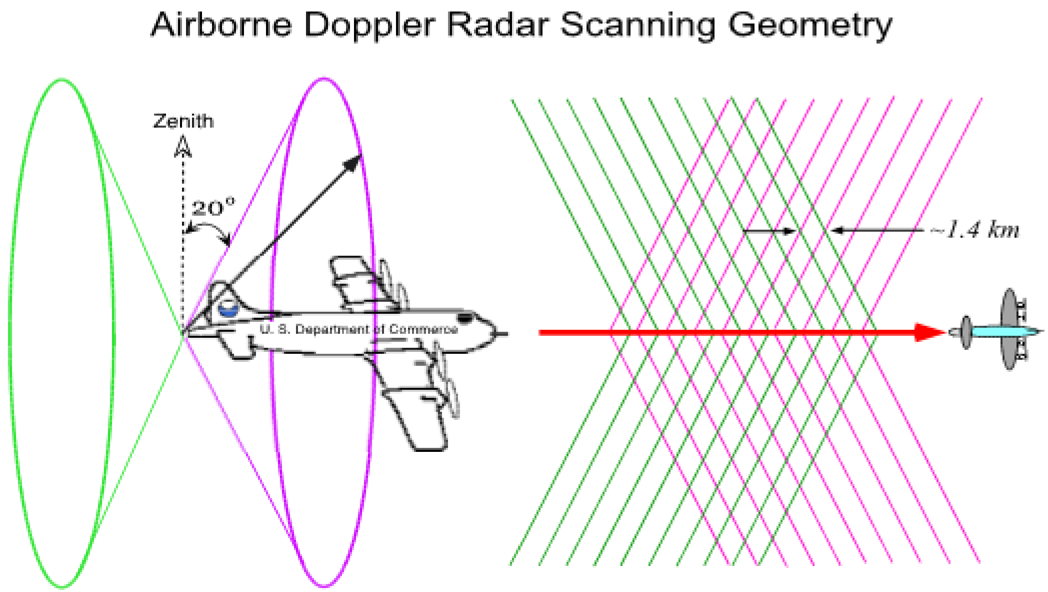


Figure 6.1.2. Tail radar scanning geometry. The left plot shows a schematic of the antenna scanning methodology. A horizontal projection of the beams is shown on the right.

Observations of the storms will need to encompass the entire vertical extent of the circulation in order to adequately derive three-dimensional motions from the pseudo-dual-Doppler technique. Accurate near-surface measurements of divergence are critical for the calculation of vertical velocity since to derive vertical motion the continuity equation is vertically integrated. To avoid the deleterious effects of vertical hydrometer velocity (plus vertical motion) it is desirable to contain the viewing to ±45° from the horizontal (2). A good rule of thumb is that R (the distance from the center of the intense precipitation core) should be greater that the distance the storm top is above the aircraft's altitude (or the surface is below the aircraft's height). For example, if the echo top, h, is 10 nmi (50,000 ft) and the aircraft altitude is 5 na mi (25,000 ft) then R is 5 na mi. If h is 50,000 ft and the aircraft altitude is 1 na mi (5,000 ft) then R is 9 na mi. Thus, low level flight patterns are desired to eliminate the (as much as possible) the contamination of radial Doppler velocity by terminal fallspeed.

One of the potential drawbacks of the high alititude flight modules is the hazard of lightning strikes on the aircraft as the plane traverses the mixed phase region between about 0° C and –5° C. The NOAA WP-3D has a tendency to become highly electrically charged in this temperature region due to impact with ice crystals. The charging has been known to completely block VHF radio transmission and reception, making contacting air traffic control problematic. It is not known if the charging has an appreciable effect on satellite communications. Static electric discharges (i.e., lightning strikes on the aircraft) are another known hazard and those discharges have been know to damage radar antennas and radar transmitters/receivers (not to mention holes drilled in the skin of the aircraft by the discharge). Therefore, to minimize damage to the aircraft the Chief Scientists should carefully monitor the environmental conditions and be prepared to move to a lower alititude if lightning strikes threaten scientific equipment or block communications with air traffic control. Decending below the melting level is usually sufficient to bleed off the charge.

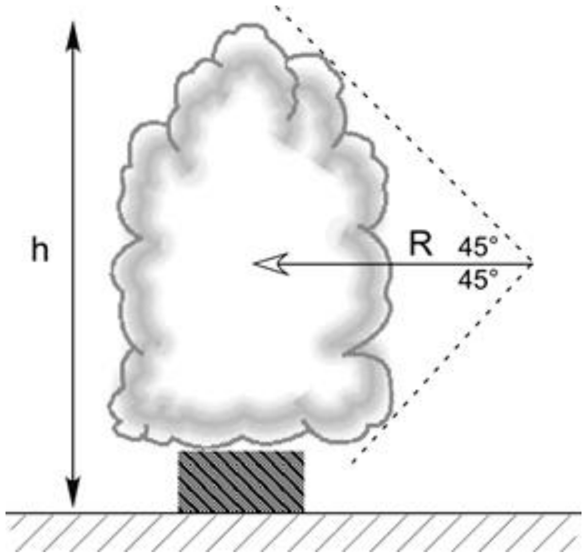


Figure 6.1.3. Schematic of desirable single aircraft airborne Doppler radar scanning at range R from the reflectivity maximum. IDeally the target is within the ±45° elevation angle to minimize the deleterious effects of the vertical fall velocity on the measured radial velocity.

NOAA WP-3D Science Mission Planning and Aircraft Operations

Decision-making protocol

The aircraft PIs will the following principles of decision-making protocol for PECAN aircraft operation. Decisions on flight plans will be based on:

1. Meteorological/oceanic conditions from all available resources including model forecasts and satellite observations, etc.
2. Science objectives yet to be met, priority will be given to provide a full coverage of MCS objectives
3. Conditions of aircraft instrumentations for specific science objectives
4. Readiness of other PECAN observational components for coordinated missions

Timing of decisions

The proper execution of aircraft missions with specific flight modules requires an established protocol for decision-making. A daily planning meeting will be conducted to make the decision on the next day's flight and details of the flight if a flight day is determined, and an outlook for possible flights in the next few days. Such decisions should be made by the science team at the end of the daily planning meeting in the form of Plan of the Day (POD).

Decisions

The most important daily decision is whether to declare the following day an “up” day or “down” day. If an “up” day is declared then secondary decisions about take-off time, likely area of operations, primary and secondary flight modules to be flown, and aircraft scientific seat allocation will need to be made to allow for airspace reservations to be made by the pilots.

Operational Rules

There are several well-established rules governing aircraft operations that NOAA has developed to insure safe flight operations. The most salient of which are:

a. There are a maximum of 6 consecutive “up” days before a mandatory “down” day has to be declared. An “up” day is defined as an alert to conduct a scientific mission. Note that an “up” day is defined whether or not a particular mission is actually conducted, i.e., a flight cancellation still counts as an “up” day.
b. After approximately 50 flight hours a mandatory aircraft inspection must be performed. This inspection shall be designated a “no fly” day, but counts as an “up” day. There might be some latitude in performing the 50 hour inspection, i.e., it could conceivably be conducted a few flight hours early or late.
c. A maximum crew duty day of 16 hours. A crew duty day is defined as when an aircrew member reports to their designated place to begin mission preflight and ends when he/she departs the work location after completion of the mission. Nominally, the pre-flight period is ~3 hours, and the post flight period, following block-in, is ~1 hour. These constraints imply that the maximum possible delay in take-off for a maximum duration mission (~9 hours) would be 3 hours. Delays longer than 3 hours would shorten the mission.
d. A minimum crew rest period of 12 hours from the time the last person leaves the airplane to the time the first person reports for next mission pre-flight. A crewmember cannot report for a subsequent preflight until the crew rest period is completed. This constraint implies a 16 hour period for consecutive flights between previous mission landing and next mission takeoff.
e. Takeoff times are set at least 12 hours in advance if the anticipated flight operations (i.e., alerts) are consistently in the same diurnal cycle, i.e., daytime or nighttime flights. If the takeoff alert is being shifted from predominately “daytime” to “nighttime” cycle or visa versa, then at least 24 hours notice is required.
f. Following 3 consecutive maximum endurance missions the NOAA AOC facility manager for the NOAA P-3 may authorize a 24-hour down period.

Aircraft scientific duties

P-3 Mission Scientist

The mission scientist will be a designated individual who is responsible for the overall scientific execution of a particular flight and acts as the primary point of contact for the AOC Flight Director. This person will communicate with the operational flight crew to execute the appropriate flight patterns and to receive real-time updates on instrument status from the instrument PIs to insure proper data gathering.

This individual will keep a detailed "event log" of significant aircraft activities (e.g., starting/ending times of flight leg segments, altitude changes, significant weather etc.), as well as keep the science crew informed of mission progress. He/she will collect all relevant data logging and reporting forms from each of the instrument specialists (e.g., radar, dropsonde, cloud physics, and observers), and provide a written report about the mission accomplishments, problems, and equipment status to the NCAR data catalog following completion of the mission. He/she conducts pre-flight and post-flight briefings/debriefings of the aircraft's crew.

Doppler Radar Scientist

This scientist monitors the performance of the radar systems (lower fuselage and tail Doppler radars), ensuring optimal operation for the selected mission. He/she works with the mission scientist in the design of the optimal flight patterns and scanning strategies for the radars, and operates the radar control computers to change operating modes (e.g., scanning strategies). This person also interprets the radar displays to ensure proper operation of the radars and keeps a detailed written log of significant meteorological events, interesting data, problems encountered with system performance, and radar configuration changes to aid in subsequent scientific analyses. This person also takes the lead in examining data on the computer workstations at the operations center following the flights to prepare products for debriefings and to ensure proper equipment operation and recording. He/she prepares sample imagery for transmission via the internet satellite link to the operations center when requested. It is likely the radar scientist and boundary layer scientist would take turns as mission scientist during a given mission depending on the flight module being flown.

Cloud Physics Scientist

The cloud physics scientist is responsible for the scientific data collection from the cloud physics sensors. He/she keeps a detailed log of the cloud penetration events, significant weather, and sensor or data recording problems, and provides a written summary to the mission scientist following the flight mission. This person also monitors and interprets the particle image displays in real time to ensure system operation and to note interesting weather events.

Post-Flight Procedures

A scientific debriefing will be held immediately after landing. The topics of debriefings are:

1. operations of all research systems.
2. aircraft status and instrument problems.
3. any problems in coordination that hampered the mission.
4. interesting scientific aspects of the flights.
5. suggestions for improvements to future flights.

This information will provide input to the next planning meeting and status reports posted to the PECAN web catalog.

Data Processing and Product Generation

Within a few days of the completion of an aircraft mission, a concerted effort will be made to produce certain standard products such as flight tracks for various modules flown, time series of meteorological variables during interesting parts of the flights, radar reflectivity time composites, etc., to ascertain the data quality and coverage. These "quick-look" plots will be posted to the web catalog. These preliminary results will be used for initial evaluation of aircraft mission accomplishments.

6.1.3 NASA DC-8

The DC-8 with its large payload carrying capability (up to 30,000 lbs), will be configured as a remote sensing platform to characterize water vapor and aerosols in the lower troposphere in advance of MCSs, prior to CI, and in the bore environment in clear air away from deep convection. The remote sensing instruments are the NASA LaRC LASE lidar and NAST-I interferometer. The basic DC-8 aircraft performance parameters are:

- Cruise speed = 450 knots (TAS) = Mach 0.80 for ISA conditions, altitudes greater than 30 kft.
- Maximum range = 5400 nautical miles with a 30,000 lb payload and 150,000 lbs fuel.
- Takeoff distance = 8500 ft with takeoff weight of 325,000 lbs, sea level, ISA conditions.
- Maximum altitude = 41 kft (12.5 km).

Further information can be found in the DC-8 Airborne Laboratory Experimenter Handbook (NASA, June 2002): http://www.espo.nasa.gov/docs/intex-na/DC8_Handbook-1.pdf

The NASA DC-8 aircraft configuration for PECAN is shown in Table I1 and Figure I1 (appendix I). The payload will includes members of instrument teams, the aircraft crew (pilot, co-pilot, flight engineer, and navigator), the mission director, assistant mission director, and two technicians. Flight safety limitations for the DC-8 are similar to those for the P3. Each participant on the platform must undergo aircraft safety training at the start of the mission. This training covers the use of emergency exits, safety equipment, and survival methods. The DC-8 will avoid hazardous weather conditions including hail/graupel, lightning, icing, and turbulence. Crew duty limits for the DC-8 are shown in Table 6.1.5. Since the DC-8 will not be housed in a hangar, even moderately severe weather (e.g. winds or hail) at the Operations Base could make the evacuation of the aircraft necessary). If such an evacuation is required, then future airborne operations could be affected, including delay of the next aircraft research sortie.

Table 6.1.5. Crew duty limitations for the NASA DC-8.

Operations – any 24 hour period	10 flight hours
Operations – any consecutive 7 days	30-40 flight hours
Operations – any 30 day period	100 flight hours
Consecutive working days	6 flight days, 10 max
Maximum crew duty period	14 hours
Minimum crew rest period	12 hours

6.2 Aircraft Functions

6.3 Aircraft Instrumentation Functions

6.4 Lidar Operations and Safety

6.4.1 UW compact Raman Lidar (down-looking)

6.4.2 Wyoming Cloud Lidar (up-looking)

6.4.3 NASA DC-8 LASE (down-looking)

NASA Langley operates a Differential Absorption Lidar (DIAL) system on the NASA DC-8 aircraft as part of atmospheric science field missions. This instrument provides high priority measurements that are mission critical to most of the airborne science missions. Specific field campaign details are provided several months before the mission which includes the location and duration of operations. This has included both operations in the United States and international operations. The full safety plan for this instrument is reproduced in Appendix O.

6.5 Single Aircraft and Coordinated Aircraft Flight Plans (Geerts, Moore et al.)

This is a placeholder for the playbook of flight patterns

6.6 Aircraft Instrument Intercomparisons and Comparisons with Fixed Ground-based Assets

The DC-8 will overfly fixed and mobile PISA sites when feasible for the purpose of intercomparisons with other ground based water vapor and aerosol lidars as well as passive sensors such as the AERIs. The DC-8 will also overfly the University of Wyoming King Air flight track (not coincident) to compare the LASE and NAST-I relative humidity profiles against the Raman lidar profiles. Ideally, one intercomparison overpass will be conducted per flight for targeted PISAs that have ground based lidar/AERI measurements

6.7 Test flights and Shake-down flights

Following instrument integration and test flights at NASA Armstrong Aircraft Operations Facility (AAOF) (Palmdale, CA), the DC-8 is expected to transit to Salina on or about June 28. One or more “shakedown” flights may need to be conducted to test communications, aircraft coordination, and decision-making process. Given the limited number of DC-8 flight hours, this shakedown process may be abbreviated to be a portion of the first science flight. If science operations are expected on the day/night of the DC-8 transit, the DC-8 may perform science legs on the transit flight before landing in Salina.

7. Mobile Platform Operational Safety (Wurman/Ziegler)

7.1 Weather, MCS/storm intercepts, and personal safety

PECAN is a large government-funded project involving universities, government laboratories, and private organizations. PECAN will have a highly visible profile in the areas where it operates and will likely receive media coverage. It is important that all crew behave safely and are perceived as behaving safely. It is important that they behave and are perceived as behaving in fashions that reflect well on PECAN, its sponsors, and all of the participating organizations.

PECAN will send about 30 vehicles and 100 people to the field. Total driving mileage will exceed 100,000 miles between 1 June and 15 July. PECAN will operate and ferry through regions experiencing severe weather including heavy rain and flash flooding, hail, lightning, and high winds, and possibly tornadoes. We may be sharing the roads (particularly before dark) with numerous other vehicles driven by storm chasers, media, local residents, other travelers, and emergency personnel. Traffic jams will occur, particularly during weekends, near metropolitan areas, when mesoscale convective systems contain intense, localized and/or long lived storm cores, or when isolated and/or long lived storms are encountered by chance during deployments to/from PECAN's nocturnal target area. Driving ability and confidence varies greatly in sub-ideal weather conditions. Many people who are watching our target convective systems will be only marginally aware of their surroundings. Therefore, we must be aware of them.

Using common sense will go a long way to keeping your and your colleagues safe. We have compiled a partial, far from exhaustive, list of specific recommendations below.

- Drive within the speed limit. Conscientiously observe all traffic laws. *No data set is worth injury.*
- Drive within a reasonable speed given the weather, road and traffic conditions. Hydroplaning on puddles and over-washed roads, reduced visibility in rain and hail and dust, cross winds, stalled vehicles, and perhaps downed power lines and other debris in the road, particularly at night, are considerable risks and may require reduced driving speeds or even pulling over and waiting until conditions improve. Know your personal limitations.
- Avoid dirt roads, which can quickly become muddy roads if rain begins falling. PECAN has generated a large list of computer-GIS-generated candidate parking sites along paved roads to be used by mobile radars and other vehicles. The cost of getting stuck on a muddy road, or worse yet sliding into a ditch, is greater than the value of getting a better dataset as a result of having taken such a road.
- Be extraordinarily wary of other drivers, particularly in severe weather conditions. Many drivers are not proficient in severe conditions. Many, including storm chasers, are distracted by the severe weather and might not be paying enough attention to safety themselves.
- Be extraordinarily alert for storm chasers stopped in the road.
- Be extraordinarily alert for storm chasers or other people on the road.
- Be extraordinarily alert for unusual behavior by PECAN radar trucks, balloon launchers, mobile mesonets, mobile PISAs, CSWR pod deployers, etc. These vehicles may stop or maneuver (e.g. three point turns to reverse direction) unexpectedly. These vehicles may have long braking distances.
- Park safely and off roads, not blocking or partially blocking lanes.
- Don’t drive after consuming alcohol or any substance that might impair driving, judgment, coordination, or reaction times.
- Don’t provide alcohol to anyone under 21 years old, even on non-mission days. It is illegal to do so. Some PECAN crew may be under 21.
- Get enough rest and sleep. Don’t drive if you are sleepy. Use a relief driver or stop.
- Know and observe the rules of individual home institutions (as explained to you by your team leaders) regarding allowed and prohibited uses of the vehicles provided by a given home

institution for scientific data collection in PECAN. Individual groups will have policies related to using official vehicles to drive to restaurants, bars, clubs or other venues. But, as a general rule, if you drive to a situation where alcohol may be ingested, have a designated sober driver.

- Watch for traffic when you leave your vehicle. Other drivers may be watching the weather and not the road.
- Wear reflective or bright clothing when outside your vehicle. If your team leader indicates that you are likely to operate in convective systems or storms with widespread heavy rain, wear a breathable, rain-repellent hooded jacket to stay warm and dry. Individual PIs may have rules for their teams. It is hard to see you at night, particularly during heavy rain.
- For PECAN's nighttime operations, it is recommended to bring a small, light-weight personal flashlight (e.g., LED) to help navigate outside around your vehicle.
- Emergency vehicles always have the right of way. PECAN science is lower priority than law enforcement vehicles, ambulances, fire trucks, etc.
- Stay inside your vehicles or minimize time outside your vehicles when lightning is a risk.
- Stay inside your vehicles or minimize time outside your vehicles when hail is a risk.
- Stay inside your vehicles or minimize time outside your vehicles when severe straightline wind is a risk. Winds over 60 mph may loft small and large debris, which can get in your eyes, cut you, etc.
- If you are in an accident, first call 911 if necessary. After immediate needs are satisfied, contact your team leader. Each team should have a list of emergency contacts and procedures provided by your team leader. If you can't contact your team leader, contact either of two emergency logistics numbers, one at the PECAN Operations Center in Hays, KS (usually primary: ; backup:) or, alternately Ling Chan, who is our Logistics Coordinator at 720-304-9100.
- If you are arrested or detained, and can't contact your team leader, contact the PECAN Operations Center in Hays, KS (usually primary: ; backup:) or alternately, Ling Chan at 720-304-9100.
- If you are lost and can't contact your PI or any other group, contact the PECAN Operations Center in Hays, KS (usually primary: ; backup:) or alternately, Ling Chan at 720-304-9100.
- Individual instrument teams have medical kits and procedures. Know what is in your group's kit. Report and treat injuries promptly.
- Inform your team leaders if you are ill.

. Practice sensible hygiene, wash hands frequently, use hand sanitizer. With 100 crew working and living in close quarters, there is a risk of infection.

- Inform your team leaders (consistent with your institutions policies) if you have any physical, mental or medical condition or limitation that might, in your best judgment, affect your ability to perform your duties, or be a risk or concern to others.
- Eat, drink, and sleep reasonably. Six weeks on the road involving extended operations well into the night will be physically and mentally taxing. If you have reasonable habits, you are more likely to stay healthy and productive.
- Don't let anyone convince you to do something that you feel is unsafe. You can refuse. Use your best judgment at all times.

To summarize, **no data set, no arrival time at a site or hotel is worth injury. Common sense behavior will go a long way towards keeping you and the rest of PECAN safe. If it doesn't feel safe,**

don't do it. If it doesn’t feel polite, don’t do it. Questions related to safety should be addressed to the team leader in charge of your instrument/vehicle/group and/or a member of the PECAN Steering Committee (Bart Geerts, Tammy Weckwerth, David Parsons, Conrad Ziegler, Josh Wurman, Matthew Parker, Kevin Knupp, Belay Demoz, Rich Ferrare, John Hanesiak, and Xuguang Wang).

PECAN operations will occur mainly after dark. Since severe weather possibly including tornadoes, hail, and strong straightline winds can occur after dark, all PECAN field participants must understand potential risks and carefully-crafted best practices that provide the best opportunity for safe PECAN after-dark operations with large numbers of vehicles.

7.2 Instruments

The instruments that we will be using during PECAN pose some risk of injury to operators and others in the vicinity. Hazards vary and are instrument-specific. To minimize the risk of injury, teams should receive training from their team leaders before and during the field project. The home institution of some teams will require completion of online defensive driver training to help insure safe vehicle operation for PECAN participants and the general public with whom we are in close proximity.

PECAN participants should also receive training from their team leaders about how to protect instruments from the conditions in which we will be operating. A few specific points to keep in mind are:

- **Dirt roads, which can quickly become muddy roads, should be avoided.** PECAN has generated a large list of computer-GIS-generated candidate parking sites along paved roads to be used by mobile radars and other vehicles. Additionally, always bear in mind that the cost of getting stuck on a muddy road, or worse yet sliding into a ditch, is greater than the value of getting a better dataset as a result of having taken such a road.
- The vehicles (with their truck- or trailer-mounted antennas or roof-mounted instrument racks) that we will be driving are much taller than the vehicles most of us typically drive. Special attention should be paid to underpasses, low-hanging trees, low-hanging power lines, and canopies/awnings at gas stations, which could easily damage or remove an expensive instrument. When height is a possible concern, and if safe, one team member should get out of the vehicle to assess the situation and direct the driver.
- Hail and strong straightline winds are unavoidable for some teams during the field project. Participants should receive instructions from their team leaders about how to minimize the damage that hail/wind could cause. Participants should also monitor situational awareness displays, other sources of weather information, and (before dark) visible storm characteristics to minimize the number of encounters with large hail in particular.

7.3 Etiquette

Wherever we go, we will be identified as part of PECAN. Our behavior will reflect on PECAN; its sponsors NSF, NOAA, and NASA; our home institutions; and the PIs and their home institutions. Common sense will go a long way in making the project enjoyable for us, and giving others a favorable impression of our project. PECAN participants should follow these guidelines:

- Don't cheer for tornadoes (although after dark during PECAN these are likely rare events) or other damage- or fear-causing weather. It is natural to want a phenomenon we are curious about to occur. But, tornadoes and other hazards are bad things for people in their paths. Remember, local residents may be in earshot and before dark you might be getting filmed.

- Do not go into straightline-wind- or tornado-damaged areas. We are not "damage tourists". PECAN might participate in formal damage surveys (perhaps as organized by a local NWS forecast office). Coordinate with cognizant Steering Committee PIs if you want to participate in a PECAN-assisted damage survey. Most PECAN crew will not be participating in damage surveys.
- Be respectful of other drivers on the road. Pass politely, and conscientiously observe all traffic laws. Don't flash lights or sound your horn unless really necessary. Other drivers may be scared by the weather.
- Be respectful of other guests at the Fort Hays State University (FHSU) lodgings and at hotels. Many PECAN crew may be staying at FHSU and perhaps forty or more PECAN crew may stay at any given hotel on extended overnight missions. After tense and exciting mission nights, it is likely that we will want to discuss the weather, what went right or wrong. But, loud parties or hallway discussions that go even later into the night could bother other guests.
- Don't do anything on the road, in a restaurant, at a bar or at a club that you, your PI, and the rest of PECAN wouldn't want to appear on TV or Youtube the next day. There may be media around; your behavior and conversations might be filmed.
- At gas stations, move away from pumps as soon as you are fueled. PECAN will have dozens of vehicles and we need to make these pit stops efficient.
- Be polite on the VHF radios. Our communications are not encrypted so anyone can listen in. If you criticize some other driver, he might hear you on the radio. If you cheer on a tornado, the Sheriff or a reporter might hear you.
- Be brief on the VHF radios. Different channels will have different rules and these rules may be different during leisurely driving as opposed to busy missions. The different channels and rules are detailed in the operations plan.
- Do not instant message, twitter, blog, or otherwise communicate PECAN target choices, forecasts, or other information outside of PECAN. We are concerned about how many chasers and local residents will be sharing the road with PECAN. Individual PIs may have specific rules concerning this issue.
- Local law enforcement personnel or local government staff may be interested in what we're doing. Within the constraints of doing your job, go out of your way to explain. We're in their towns and depend on local goodwill for our operations.
- Be polite to the media. You may be indifferent, love, or hate them, but they are doing their jobs too. Some of them may have been invited to follow PECAN by various PECAN groups. Some are less integrated. PECAN, its sponsoring agencies NSF, NOAA, and NASA, and the home institutions of the PIs, benefit from favorable portrayal in the media. Make sure that your actions contribute to such a favorable portrayal.

8. PISA Operations (Turner)

8.1 Fixed PISA sites, capabilities and staffing

Table 8.1.1. Nearest city, latitude and longitude for the fixed PISA units and S-POL.

Fixed PISA	Nearest Town	Latitude (N)	Longitude (W)
FP1	ARM site	36.6070	97.4880
FP2	Greensburg	37.606121	99.275643
FP3	Ellis	38.9582	99.5742
FP4	Minden	40.5153	98.9511
FP5	Brewster	39.3576	101.3710
FP6	Hesston	38.14386	97.43883
S-POL	40 km SW of Hays	38.553500	99.536083

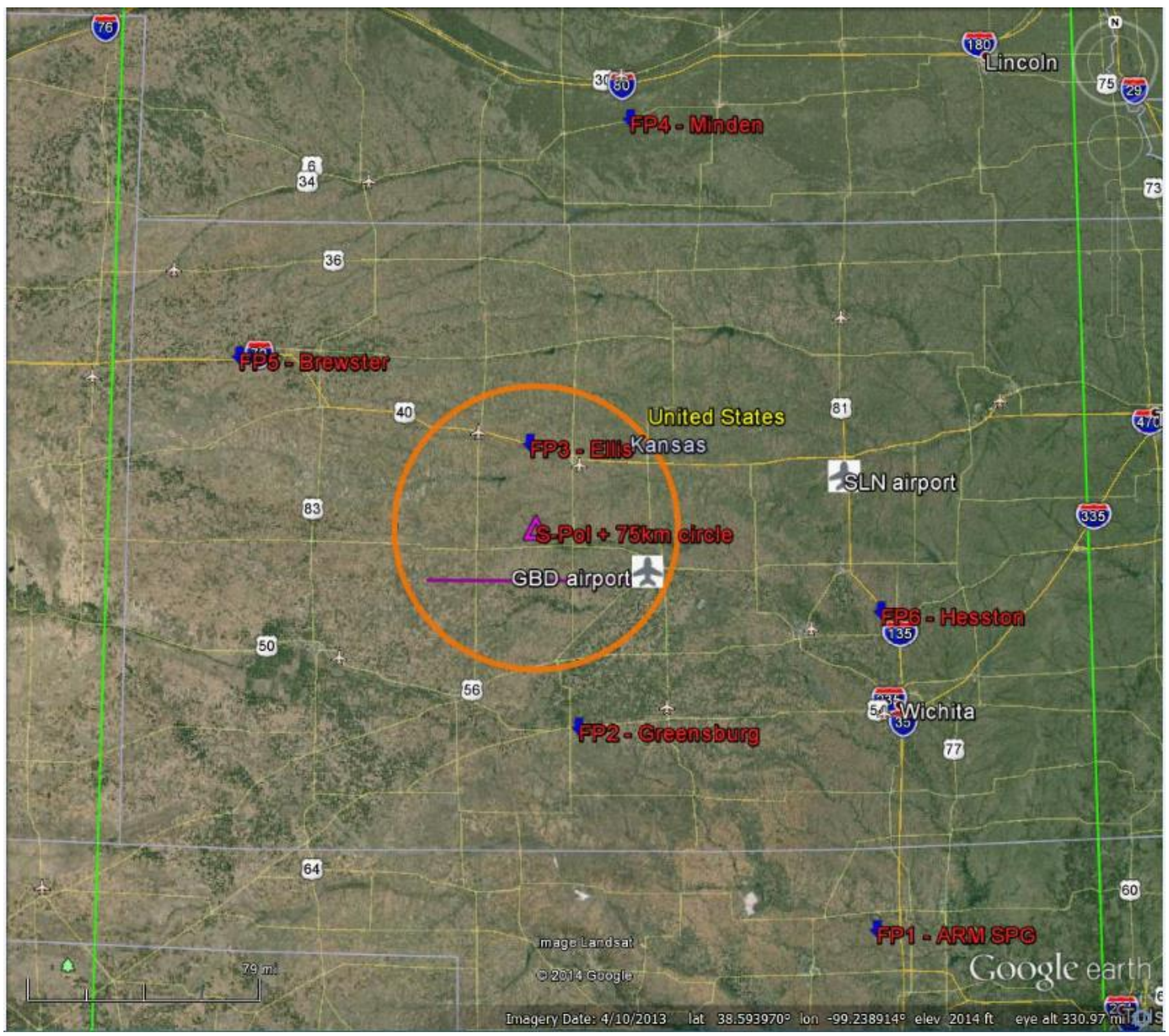


Fig. 8.1.1. Fixed PISA locations and location of S-POL (with a 75 km circle.) Pink line is fixed

flight track for UWKA LLJ missions.

Table 8.1.2: Proposed fixed PISA units. Note: “sfc met” = surface meteorological measurements.

ID	lead PI	instrument source	instruments
fixed profiling units (FP): stationary during the duration of PECAN, operating continuously			
FP1	David Turner	DOE ARM SGP Central Facility	wind lidar, Raman lidar, AERI, MR, sfc met and sfc fluxes, radiosonde unit (increased freq. due to accepted ARM proposal), four 915 MHz WPs with a typical spacing of 10 km, C-band scanning radar, cloud radars, radar wind profilers, DL, eddy covariance systems. (Up to three X-band scanning radars might be available if fixed in time.)
FP2	Qing Wang + Belay Demoz	Howard Univ	Radiosondes and MR
		NASA/GSFC	RL and DL
		UMBC	Doppler lidar and MPL
		DOE ARM	AERI
		Naval Postgraduate School	Sodar & sfc met & tethersonde & flux tower
FP3	Rich Clark + Bill Brown	NCAR EOL	ISS-449, WV-DIAL
		University of Manitoba	MR and DL (zenith staring only)
		Millersville University	1000 m tethersonde profiles of met. variables/turbulence, sfc met. and sfc fluxes, backscatter lidar, sodar, and radiosonde unit
		DOE ARM	AERI

FP4	Bill Brown	NCAR EOL	ISS with 915 MHz WP, GAUS, GPS, sfc met
		DOE ARM	AERI
FP5	Bill Brown	NCAR EOL	ISS with 915 MHz WP, sodar, GAUS, GPS, sfc met
		DOE ARM	AERI
		Brookhaven Nat. Lab	MR
FP6	John Hanesiak	Univ. of Manitoba	MR, DL
		DOE ARM	radiosonde unit (~150 radiosondes with balloons and helium) and AERI
		Univ Alabama Huntsville	Sfc met

8.2 Mobile PISA capabilities and staffing

Table 8.2.1: mobile profiling units (MP): operate during IOPs only			
MP1	Petra Klein + David Turner	U. Oklahoma, NSSL	CLAMPS: AERI, MR, and scanning DL
		U. Oklahoma	radiosonde & sfc met
MP2	Kevin Knupp	Univ. of Alabama Huntsville	MIPS: scanning Doppler lidar, 915 MHz WP, X-band radar, MR, sodar, ceilometer, sfc met, radiosonde unit
MP3	Nadia Smith / Wayne Feltz	U. Wisconsin	SPARC: AERI + multi-spectral aerosol lidar + DL, ceilometer, sfc met, radiosonde unit
MP4	Bill Brown	NCAR EOL	Mobile ISS with 915 MHz WP, MGAUS, sfc met
MP5	Dave Parsons /	Naval Postgraduate	TWOLF Doppler lidar & FM-

	Howie Bluestein	School / OU	CW radar (both truck-mounted) + sfc met

8.3 Mobile PISA operations

The mobile PISAs have different missions, depending upon the particular PECAN mission that has been selected for the IOP. For the MCS, CI, and Bore missions, the MP deployment plan is to be deployed in coordination with the mobile radar hexagon (Fig X below). In each case, the orientation of the MPs depends on the anticipated direction of the event.

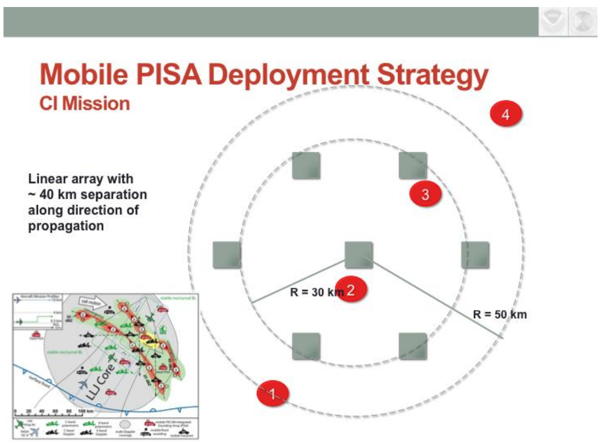


Fig Xa: MP deployment strategy for the CI mission. In this example, the LLJ core is forecast to approach from the SSW (as indicated in the inset image on the lower left). The MPs are aligned along the LLJ axis, with MIPs (MP-2) near the center of the mobile radar hexagon, CLAMPS (MP-1) and SPARC (MP-3) on either side but near or just outside the radar ring, and MISS (MP-4) further downstream.

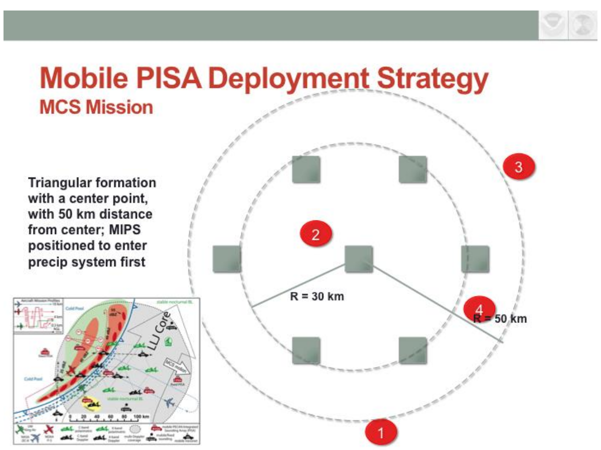


Fig Xb: MP deployment strategy for the MCS mission. In this example, the storm is propagating from the WNW towards the ESE. MIPS (MP-2) is within the mobile radar ring, but shifted towards the storm. CLAMPS (MP-1) and SPARC (MP-3) are further downstream, just outside the radar ring but within dual-doppler coverage. MISS (MP-4) is along the line between CLAMPS and SPARC, or perhaps slightly more downstream.

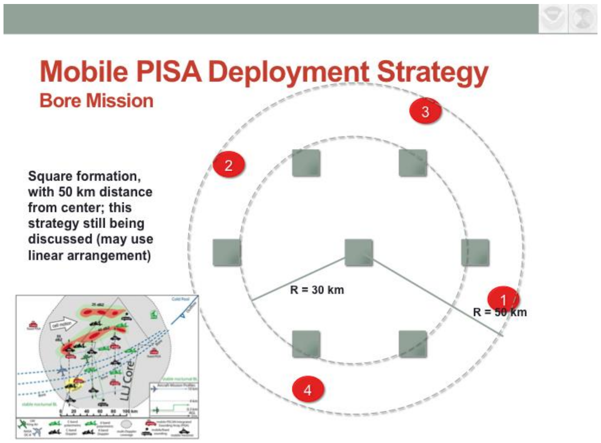


Fig Xc: MP deployment strategy for the Bore mission. In this example, the storm motion is to the west, and the outflow is expected to propagate southward. This is one potential configuration; however, the configuration used for the CI mission may also be used.

Fig X: MP deployment plans for the 3 PECAN missions. The gray squares denote the nominal positions of the 7 mobile radars. The red circles (1-4) denote the 4 MPs. Note that these configurations assume that there is no fixed PISA within the radar hexagon. If the hexagon includes a FP, then the MP coordinator will rearrange the MPs to incorporate the 5th profiling site.

8.4 Radiosonde Deployment Strategy (Lim)

9. Radar Operations

9.1 S-Pol location and scanning strategies (Weckwerth)

S-Pol Location

NCAR's S-Pol radar will be located at:
Latitude: 38° 33' 12.6"N
Longitude: 99° 32' 9.9" W
Elevation: 2149 ft ASL

This site 0.26 miles west of Cty Rd 130 on the north side of Hwy 4; ~40 km SW of Hays, KS and 4.4 km SE of McCracken, KS.

S-Pol can be operated remotely but the intent is to staff S-Pol during nighttime IOPs.

S-Pol Scanning Strategies

The plan is to scan S-Pol continuously during all of PECAN, except for some daytime downtime periods due to radar and generator maintenance. S-Pol will be operated with a 1.5 µs (225 m) pulse width to enhance the sensitivity by ~3 dB with a goal of maximizing clear-air return. Oversampling will be done to process gates at 150 m spacing. Regardless of which scanning mode is being exercised, a low-level refractivity/rainfall scan will be taken at least every 5 min. This will be a 360° surveillance scan at 0° or 0.2° elevation angle, depending on blockage, with a scan rate of 8 deg/sec.

While specific scanning information is provided below, changes are likely based on the experience and desire of the scientists present. This plan is summarized in Table 9.1.1.

1. Unattended mode (no S-Pol scientist on duty): This will be a 10 min sequence of several surveillance scans and 11 RHIs. There will be 5 min, 15 sec of surveillance scans at a scan rate of 8 deg/sec. The scanning sequence will be at elevation angles of 0°,0.5°, 1.4°, 2.5°, 3.6°, 5.0° and 7.0°. This will be followed by 4 min, 35 sec of RHI scans to look for the presence of wave features. The RHI scans will be done from the surface to 45° every 30°.
2. Surveillance mode: This is the same as unattended mode except that the scientist on duty is free to make desired changes based on the waves and/or weather observed. No specific PECAN experiment is being conducted.
3. CI experiment mode: Unattended scanning mode (10-min cycle) will be used until CI features of interest are detected. Then surveillance and RHI scans will be done on a 5 min cycle. Seven surveillance scans will be done at 12 deg/sec and 9 RHIs at 3 deg/sec will be added to focus on the vertical structure of the developing convection. If a particular region of development can be identified, then 12 PPI scans will be done within a ~120° sector, followed by 9 RHIs. This sequence will be completed within the 5-min cycle time.
4. MCS experiment mode: Unattended scanning mode (10-min cycle) will be used until MCS features of interest are within S-Pol range. Then surveillance/PPIs and RHI scans will be done on a 5 min cycle. Seven surveillance scans will be done at 12 deg/sec and 9 RHIs at 3 deg/sec will be added to focus on the vertical structure of the evolving convection. If a particular region of interest can be identified, then ~12 PPI scans will be done, followed by 9 RHIs. This sequence will be completed within the 5-min cycle time.
5. Bore experiment mode: Unattended scanning mode (10-min cycle) will be used until bore features are expected or are observed. Then surveillance and RHI scans will be done on a 5 min cycle. Seven surveillance scans will be done at 12 deg/sec and 9 RHIs at 3 deg/sec will be added to focus on the vertical structure of the bore emerging and propagating away from the MCS.
6. LLJ experiment mode: Unattended scanning mode (10-min cycle) will be used until a LLJ experiment is called. Then surveillance and RHI scans will be done on a 5 min cycle. Seven surveillance scans at 12 deg/sec will be followed by 9 RHIs at 3 deg/sec to focus on the axis of the LLJ.

Table 9.1.1: S-Pol scanning strategy for PECAN.

Experiment	Scan time (min)	Sur elev. angles (deg)	Sur scan Rate (deg/sec)	PPI sector width/ elev. angles (deg)	PPI scan Rate (deg/sec)	RHI's Num/depth	RHI scan Rate (deg/sec)
CI Unattended	10	0.0, 0.5, 1.4, 2.5, 3.6, 5.0,	8	none	none	11every 30deg/0=45	3

and attended prior to focus area specified		7.0				deg	
CI focus area specified	5	0.0, 0.5, 1.4, 2.5, 3.6, 5.0, 7.0	12	none	none	9 at sci specifed azm	3
CI starting	5	0.0	12	120 deg/ 12 sci specified	12	9/at sci specified azm	3
MCS unattended	10	0.0. 0.5, 1.4, 2.5,3.6,5.0, 7.0	12	none	none	9/ every 30 deg/0-45	3
MCS focus area specified	5	0.0, 0.5, 1.4, 2.5, 3.6, 5.0, 7.0	12	none	none	9/ sci specified	3
MCS specified PPI area	5	0.0	12	120 deg/ 12 sci specified	12	9 /sci specified	3
Bore unattended	10	0.0, 0.5, 1.4, 2.5, 3.6, 5.0, 7.0	12	none	none	9 /every 30 deg/0-45	3
Bore expected or observed	5	0.0, 0.5, 1.4, 2., 3.6, 5.0, 7.0	12	none	none	9/ sci specified	3
LLJ experiment specified	5	0.0, 0.5, 1.4, 2.3, 3.6, 5.0, 7.0	12	none	none	9 /sci specified across axis LLJ 0-45 deg	3

9.2 ARM Radar Operations (Turner)

9.3 Mobile Radar Capabilities and Operations (Wurman/Kosiba/Biggerstaff/Ziegler - Draft)

There are eight mobile radars participating in the field campaign (Table X). Seven of the radars will be deployed in a hexagonal shape to maximize multi-Doppler coverage of the meteorological phenomena of interest. The specific configurations and scan parameters will be discussed below in the context of IOP type.

Radar	Wavelength	Peak Power	Beamwidth	Polarization	Primary Mission
SR1	C-Band/5 cm	250 kW	1.5	Single	Multi-Doppler Hexagon
SR2	C-Band/5 cm	250 kW	1.5	Dual	Multi-Doppler Hexagon
DOW6	X-Band/3 cm	250 kW x 2	0.9	Dual	Multi-Doppler Hexagon
DOW7	X-Band/3 cm	250 kW x 2	0.9	Dual	Multi-Doppler Hexagon
DOW8	X-Band/3 cm	250 kW	0.9	Single	Multi-Doppler Hexagon
NOXP	X-Band/3 cm	250 kW	0.9	Dual	Multi-Doppler Hexagon
MAX	X-Band/3 cm	250 kW	0.9	Dual	Multi-Doppler Hexagon
RaXPOL	X-Band/3 cm	20 kW	1.0	Dual	Co-located with TWOLF/BL studies

Table X. Summary of the mobile radars participating in the PECAN field campaign. Detailed specifications for each radar system are provided in the Appendix.

Radar	Mobile Radar PI	Email
SR1	Biggerstaff	drdoppler@ou.edu
SR2	Biggerstaff	drdoppler@ou.edu
DOW6	Wurman (primary); Kosiba (secondary)	jwurman@cswr.org; kakosiba@cswr.org
DOW7	Wurman (primary); Kosiba (secondary)	jwurman@cswr.org; kakosiba@cswr.org
DOW8	Wurman (primary); Kosiba (secondary)	jwurman@cswr.org; kakosiba@cswr.org
NOXP	Mansell (primary); Burgess (secondary)	ted.mansell@noaa.gov; donald.burgess@noaa.gov
MAX	Knupp	kevin@nsstc.uah.edu
RaXPOL	Bluestein	hblue@ou.edu

Table Y. Mobile radar PIs.

9.3.1 Radar Deployment Protocol and Logistics

Radar Readiness: The mobile radar facility providers (Table Y) will communicate the status of their radar(s) to the Mobile Radar Coordinator (MRC) at least 1 hour before the start of the daily forecast briefing.

Radar Staffing: Each mobile radar will be crewed by at least 2 people. The radar facility provider will provide a crew list and phone numbers to the MRC.

Deployment Locations: Deployment locations will be chosen based on a GIS database of locations (see section 9.3.5).

Information Provided to Mobile Radar Teams (MRTs): Before departing for an IOP, the MRC will give each MRT the following information:

1. Start time of IOP
2. Initial deployment location (or waypoint)
3. Expected arrival time at initial deployment location (or waypoint)
4. Expected scan strategy
5. Expected end time of IOP
6. Expected overnight location
7. Any specific, additional times they need to check-in with MRC
8. Approximate start time and location of Day 2 IOP

Arrival at Deployment Location: For all IOPs, unless otherwise specified, the seven radars that are part of the multi-Doppler array will arrive at their preliminary deployment location at least 1.5 hours before the scheduled start of the IOP. This is to ensure ample time for siting, set-up, and any preliminary data collection/testing. Each radar team will check-in with the MRC upon arrival at their pre-determined site. Each radar team will then immediately assess if the site is suitable for operations and communicate the suitability of the site to the MRC. Radar teams will also communicate to the MRC the cell connectivity and VHF radio communication to the other radars.

Before IOP: Once a radar is deployed at the site, the radar will take several clutter scans for later navigation of the data. If the radar is deployed before sunset, the radar will perform a solar alignment *BEFORE* the clutters scans.

Communication during IOP: (1) Verification of radar scanning strategies will be communicated from the MRTs to the MRC. The MRC will coordinate any change in scanning strategy during the IOP. (2) If a radar goes "down" during an IOP, the radar team needs to immediately notify the MRC. The MRC in consultation with the mission scientist will decide if the mobile network should be modified to account for the missing radar coverage. (3) The MRC along with the nowcaster will communicate weather threats (large hail, extreme winds, and flash flooding) to the MRTs. (Want info from nowcasters and also the ability for nowcasters to annotate on field catalog.) The MRC along with the MRTs will decide if the severe weather warrants action (e.g., stop scanning and point antenna away from hail, etc.). Ultimately, it is up to individual mobile radar teams to decide the best course of action, but they need to communicate their decision to the MRC.

Unable to reach the MRC: In the event that a radar team is unable to reach the MRC, they should contact the operations center. Or, if they are in radio range of another radar, they should communicate to the other radar that they are unable to reach the MRC and may be able to communicate with the MRC via the other radar.

End of IOP: Approximately one hour before the scheduled end time of the IOP, the MRC will update the radar teams on the anticipated end time of the IOP (e.g., IOP end time unchanged, will operate an extra hour, etc.). The MRC will notify the radar teams when the IOP has ended. Before ending data collection, each radar team must receive confirmation from the MRC.

Departure from Deployment Location: (1) Each MRT will email a summary report of their operations to the MRC before departing their site. A template of the form is in Appendix X. (2) Before the radar teams leave their deployment locations, they should be informed of any hazards, change of overnight location, etc. by the MRC. Also, if a radar team feels it would be unsafe for them to drive to the overnight location (e.g., they are all fatigued), they need to communicate and work with the MRC to make alternate plans. Each of the seven radar teams will notify the MRC when they are leaving their deployment site. A route forecast (e.g., road conditions, flooding, etc.) will be provided by the nowcaster on the field catalog for the MRTs. The MRC's shift at the OC ends at the end of the IOP.

Ferry to Overnight Location: Each radar teams will check-in with the designated overnight staff at the OC upon arrival at the overnight location (Hays or a hotel). If there are problems encountered during the ferry (e.g., flat tire, stuck in mud), the overnight staff at the OC will help coordinate local help for the impacted teams (e.g., a ride back to the hotel, help getting a tow from another team), if needed. The MRTs and the mobile radar PIs are ultimately responsible for getting to the overnight (or alternative overnight) location after an IOP.

MRC IOP Summary: The MRC will complete a radar mission summary (template provided in Appendix X) by 1200 CDT the following day.

9.3.2 Example Work Timeline for MRC during IOP

Approximate Time (CDT)	**Mobile Radar Coordinator (MRC)**	**Mobile Radar Teams (MRT)**
1400 (Day 1)		Mobile radar PIs provide facility status to field catalog and MRC
1500 (Day 1)	**Forecast Briefing.**	**Forecast Briefing.**

1530 (Day 1)	**Plenary Meeting.** Mission Proposals	
1545 (Day 1)	**MST Meeting.** MRC works with MST to pick mobile radar hexagon center, diameter, and orientation	Vehicle Preparation
1615 (Day 1)	MRC communicates to Mobile Radar PIs and MRTs deployment info.	MRC communicates to Mobile Radar PIs and MRTs deployment info.
1630 (Day 1)	As teams depart, MRC works with MST to make a preliminary decision RE Day 2 location (i.e., center of hexagon and start time of IOP)	Depart Hays, KS.
1630 – 1830 (Day 1)	MRC works with MST to refine deployment locations based on site constraints, evolution of the weather, radar readiness. Hexagon center and vertices adjusted, as needed. MRC offers input and other deployment options to MST.	Ferry to deployment
1830/1930 (Day 1)		MRTs arrive at deployment locations
2000/2100 (Day 1)	**Start of ops**	**Start of ops**
2030 (Day 1)	Finalize guidance for Day 2 location. Revisions for Day 2 and center of hexagon. Decide if teams come home or stay out. MRC gets info from facility providers about their overnight decisions.	
2100 (Day 1)	Finalize overnight plans	
2000/2100 – 0200/0300 (Day 1)	Discussion at OC of mission end times, end criteria, etc. Communicate hazards (e.g., hail, flooding) and offer guidance to	**Data collection.** Communicate to MRC hazards, operational status, etc.

	MRTs.	
0200/0300 (Day 1)	**End of IOP.** End of shift. OC staffer takes over getting MRTs home.	**End of IOP. Submit mission summary to MRC.** Ferry to overnight location. Some MRTs may end earlier as the phenomena moves out of their coverage (west to east).
0400/0500 (Day 1)		Check-in with OC upon arrival at overnight location.
1100 -1200 (Day 2)	Notify mobile radar PIs (and MRTs) if Day 2 IOP timing has changed.	
1200 (Day 2)	Radar summary of Day 1 operations posted to field catalog	
1330 (Day 2)		Check-in with MRC for Day 2 preliminary IOP information

9.3.3 Radar Scan Strategies and Deployment Configurations

Below are several factors that will guide the MRC decision

- If center radar goes out -> Will always try to move an asset
- If vertex radars goes out -> May or may not move an asset depending on logistics and time available.
- Base network geometry is equilateral triangle to optimize triple Doppler retrievals
- Center radar site (DoW7) highest priority (360 view with minimal blockage). Next priority is for C-bands due to lower attenuation concerns.
- For MCS missions, C-band baseline should be perpendicular to MCS propagation vector and initially closest to convective region.
- Blockage for Vertex sites: Optimize what it happening in the hexagon (will the PISAs optimize for this?). Clear 180 deg sectors in the hexagon.
- Cab blockage: along baseline or into blockage. Central site should reorient heading as convection moves past to coordinate with second set of radars. The leading edges of convective segments are higher priority for central site coordination than trailing stratiform region.

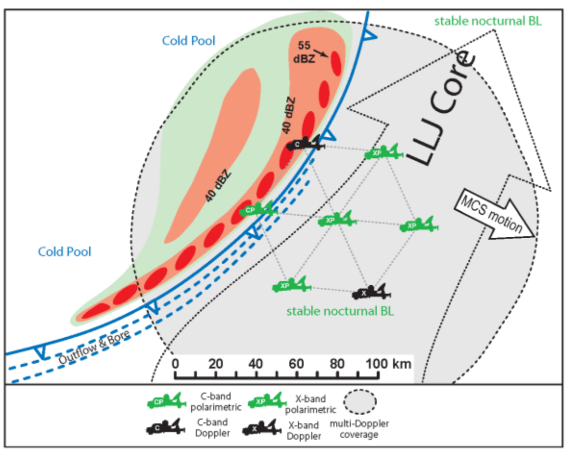
9.3.3.1 MCS Missions

Hexagon with C-band baseline perpendicular to forecast MCS motion vector and closest to advancing convective region. NOXP radar on vertex adjacent to SR2 with UAH-MAX on vertex adjacent to SR1. Central radar is DOW7, which will scan to higher max elevation angle than other radars. DOW6 will take far side vertex with best route to DOW7, as DOW6 will serve as the primary backup to DOW7 at the central site. DOW8 assigned to the remaining vertex. This configuration provides optimal dual-pol coverage as the single-pol radars (SR1 and DoW8) are flanked by dual-pol systems (Figure X). An alternative configuration is Figure XX.

Baselines: 30 ± 5 km

Scan Strategies: The mobile radars will have 3 different scan strategies, contingent upon the range of the precipitation from the individual radars. When the precipitation is out of range, that radar will operate in "Clear Air" Mode (CAM); when the precipitation is within unambiguous range but convection is greater than 50 km range, the radar will operate in a "Precipitation" Far Mode (PFM). When the convection is within 50 km range, that radar will operate in a Precipitation Near Mode (PNM). CAM is optimized for boundary layer coverage and greater sensitivity within 50 km of the radar, whereas PM is optimized for capturing tropospherically deep storm-scale processes.

At 30 km in range, the C-band radars, with a 1.5-deg beam, have an ~800 m beamwidth (Δ), which allows for the resolution of features ~4Δ = 3.2 km. The X-band systems, with a 0.9-degree beam, have a beam width of ~500 m, resolving features of ~4Δ = 2.0 km.



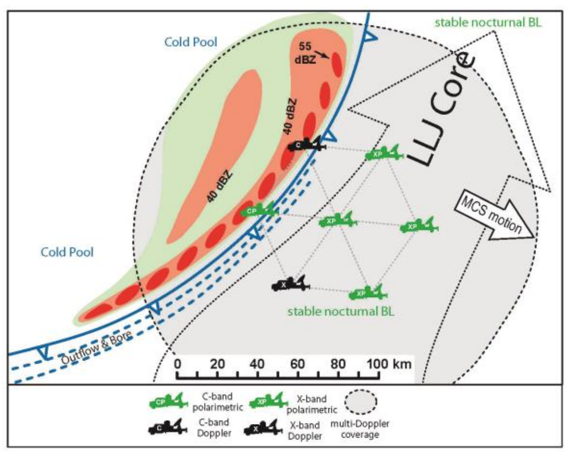


Figure X. *Figure XX.*

9.3.3.1.1 MCS Missions: MCS-PFM (nearest precip > 50 km range)

At a distance of 50 km, from a given radar, the vertical domain extends from ~0.6 km ARL to ~15 km ARL.

Radar	**SR1**	**SR2**	**DOWs 6,7**	**DOW8**	**NOXP**	**MAX**
Polarization	Single	Single	STSR	Single	STaR	STaR
PRF (Hz)	900/600 (Stagger)	900/600 (Stagger)	1000/1250 (Stagger)	1000/1250 (Stagger)	1250/937 (Stagger)	
Nyquist	±24	±24	±40	±40	±30	

(m/s)						
Max Range (km)	166	166	120	120	120	
Pulse Length (us)	1.0	1.0	0.8	0.8	0.5	
Gating (m)	150	150	60 (Oversampled)	60 (Oversampled)	75	
Sync Minute	5	5	5	5	5	5
Scan Rate (deg/sec)	20	20	25	25	20	20
Num. of Tilts	14	14	16	16	14	14
Angle List	SR-PFM1	SR-PRM1	DOW-PRM1	DOW-PFM1	NOXP-PRM1	MAX-PFM1

9.3.3.1 MCS Missions: MCS-PNM (nearest precip < = 50 km range)

At a distance of 30 km, from a given radar, the vertical domain extends from ~0.6 km ARL to ~23 km ARL.

Radar	**SR1**	**SR2**	**DOWs 6,7**	**DOW8**	**NOXP**	**MAX**
Polarization	Single	STaR	STSR	Single	STaR	STaR
PRF (Hz)	1500	1500	2000/2500 (Stagger)	2000/2500 (Stagger)	1700/1275 (Stagger)	
Nyquist (m/s)	±20	±20	±80	±80	±40	
Max Range (km)	99	99	60	60	88	
Pulse Length (us)	0.5	0.5	0.4	0.4	0.5	0.4
Gating (m)	75	75	60	60	75	
Sync Minute	5	5	5	5	5	5
Scan Rate (deg/sec)	25	25	50	50	30	30

Num. of Tilts	18	18	40	40	23	23
Angle List	SR-PNM1	SR-PNM1	DOWDP-PNM1	DOW-PNM1	NOXP-PNM1	MAX-PNM1

9.3.3.2 CI Missions

Hexagon with DoW6/DoW8 baseline perpendicular to forecast storm motion vector and closest to expected CI region. NOXP radar on vertex adjacent to DoW6 with UAH-MAX on vertex adjacent to DoW8. Central radar is DoW7. SR2 will take far side vertex with best route to DoW7, as SR2 will serve as the primary backup to DoW7 at the central site during CI missions. SR1 assigned to the remaining vertex. This configuration provides optimal dual-pol coverage as the single-pol radars (SR1 and DoW8) are flanked by dual-pol systems. Also, the higher sensitivity of the X-bands will provide better coverage of the boundary layer with the C-bands suffering less attenuation after CI when the storms move across the network (Figure Y). An example alternate configuration, if three radars were to be unavailable, is shown in Figure YY.

Baselines: 20 ± 5 km

Scan Strategies: Can add either 2 or 5 minutes of RHIs (Section 9.3.3.3), depending on the choice of either CI5 or CI8 and depending on the desired sync rate. The only difference between CI5 and CI8 is the scan rate and number of PPI sweeps. May switch to MCS mode (MCS-PNM) once convection has developed within 50 km range of a radar. The sync period is either on 5 or 10 minutes (e.g., CI5+RHI5 or CI8+RHI2). RHI options are provided in Section 9.3.3.3.

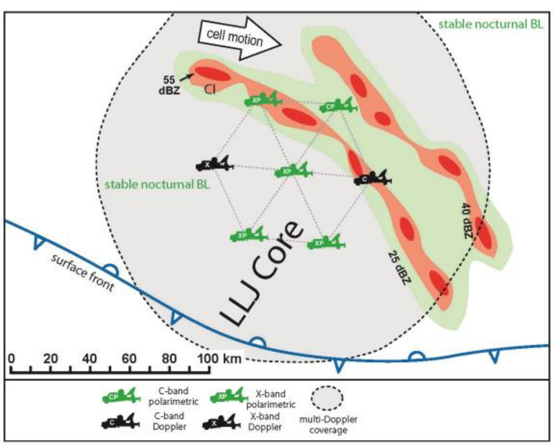


Figure Y.

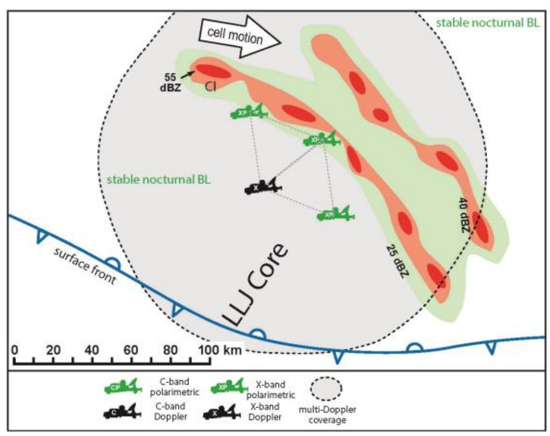
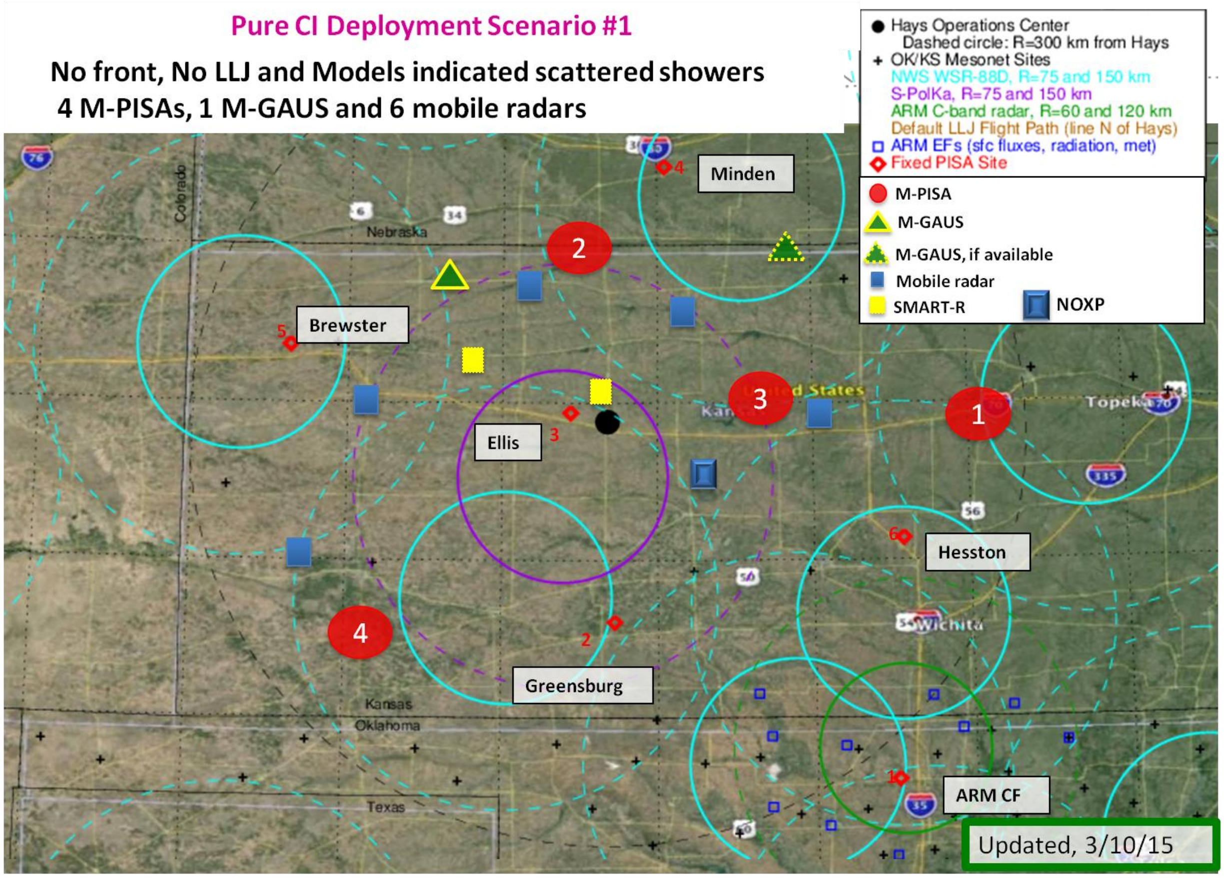
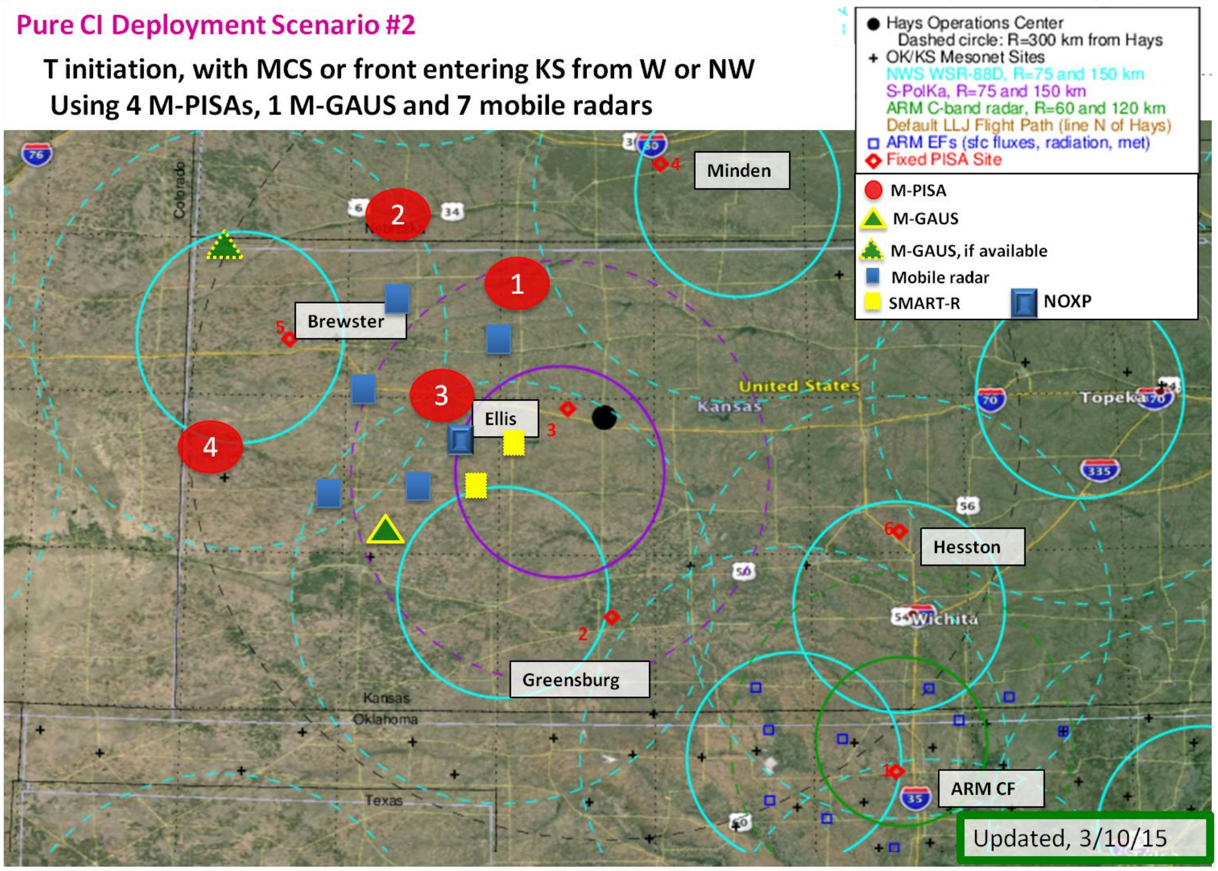


Figure YY.

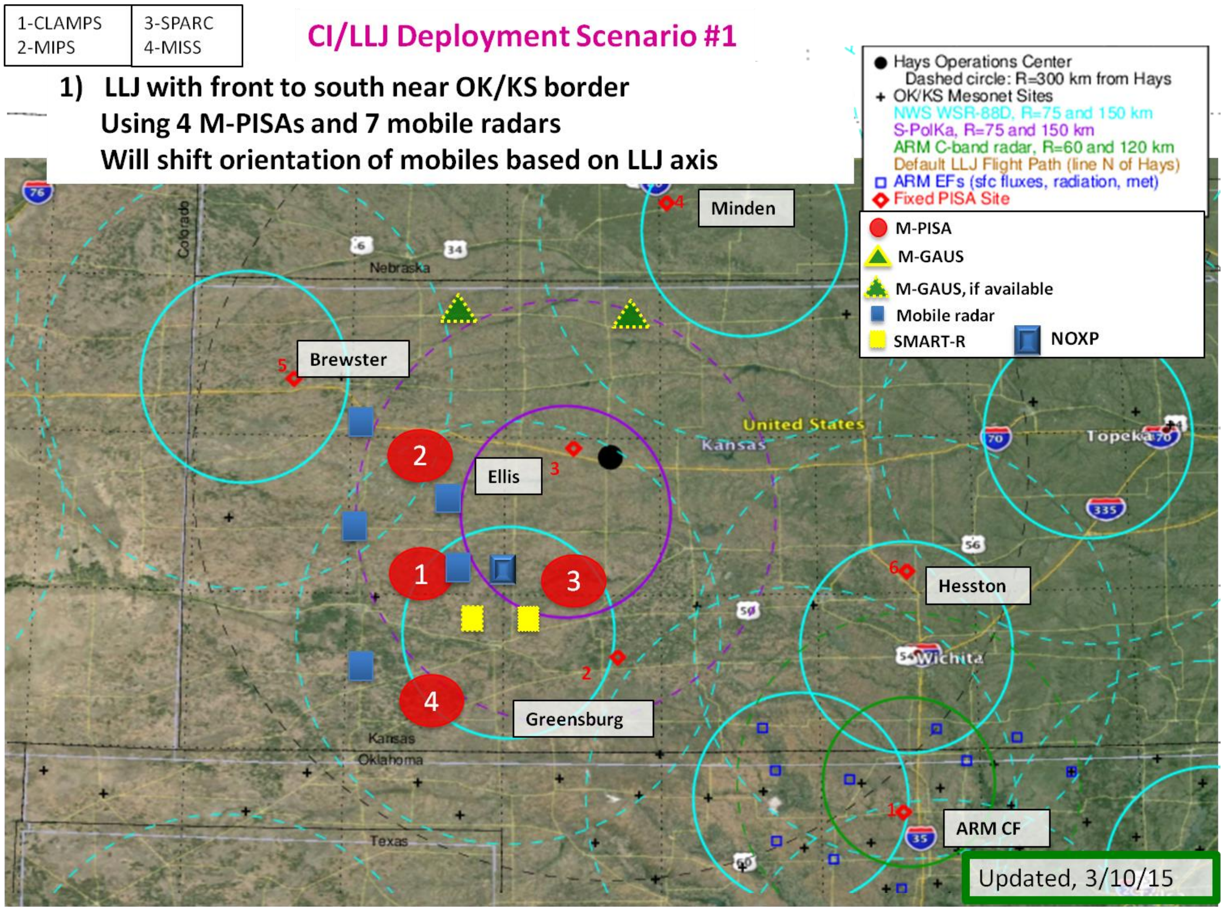
Further potential deployment scenarios are planned. All mobile radars are not required for all CI missions but if available, the following are preferred deployment scenarios. If the forecast indicates a chance of scattered storms with no front and no LLJ, this is the preferred deployment scenario centered around S-Pol:



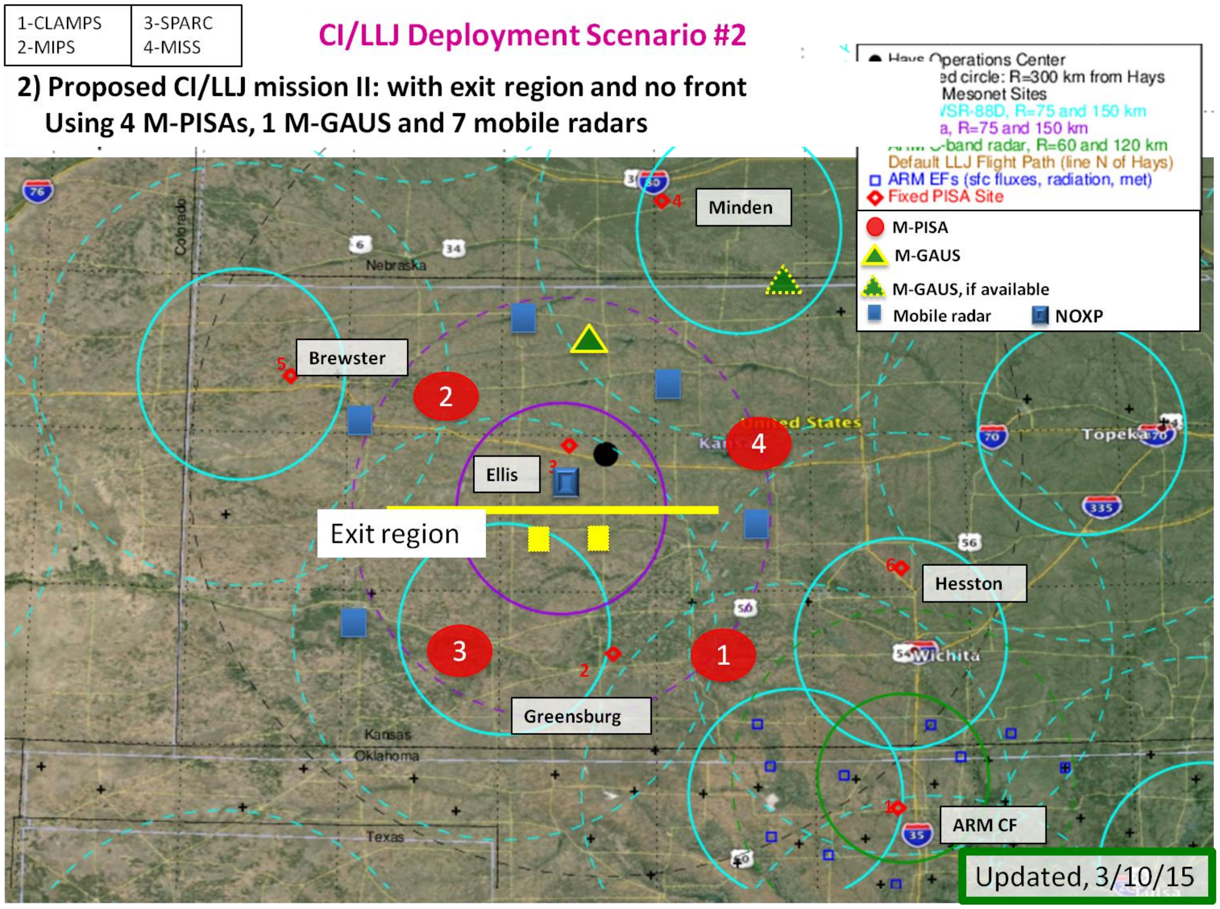
This is the desired relative deployment scenario when there is an MCS or front entering KS from the west or northwest with expected initiation in advance:



When CI is expected in association with a nocturnal LLJ and a stationary front to the south of the domain, we will use this deployment scenario:



When CI is expected in association with a nocturnal LLJ without a front, we will use this genearl deployment plan:



9.3.3.2.1 CI Mission with 5-minute volumes (CI5)

Radar	SR1	SR2	DOWs 6,7	DOW8	NOXP	MAX
Polarization	Single	STaR	STSR	Single	STaR	STaR
PRF (Hz)	900	900	1000/1250 (Stagger)	1000/1250 (Stagger)	900/675 (Stagger)	
Nyquist (m/s)	±12	±12	±40	±40	±21.5	
Max Range (km)	166	166	120	120	166	
Pulse Length (us)	1.0	1.0	0.8 us	0.8	1.0 us	1.0 us
Gating (m)	150	150	60 (oversampled)	60 (oversampled)	150	
Sync Minute	5	5	5	5	5	5

Scan Rate (deg/sec)	12	12	15	15	12	12
Num. of Tilts	9	9	12	12	9	9
Angle List	SR-C5	SR-C5	DOW-C5	DOW-C5	NOXP-C5	MAX-C5

9.3.3.3.2 CI Mission with 8-minute volumes (CI8)

Radar	**SR1**	**SR2**	**DOWs 6,7**	**DOW8**	**NOXP**	**MAX**
Polarization	Single	STaR	STSR	Single	STaR	STaR
PRF (Hz)	900	900	1000/1250 (Stagger)	1000/1250 (Stagger)	900/675	
Nyquist (m/s)	±12	±12	±40	±40	±21.5	
Max Range (km)	166	166	120	120	166	
Pulse Length (us)	1.0	1.0	0.8	0.8	1.0 us	1.0 us
Gating (m)	150	150	60 (oversampled)	60 (oversampled)	150	
Sync Minute	8	8	8	8	8	8
Scan Rate (deg/sec)	7	7	10	7	7	7
Num. of Tilts	9	9	12	9	9	9
Angle List	SR-C8	SR-C8	DOW-C8	DOW-C8	NOXP-C8	MAX-C8

9.3.3.2 Bore Missions

9.3.3.2.1 Bore occurring with MCS

Hexagon configuration same as MCS.

Baseline 25± 5 km for declared Bore mission.

We will use MCS-PFM and MCS-PNM, as described above. Since the dual-pol, dual-frequency DOWs can scan faster than the other radars, an alternate angle list that includes a complete volume with added RHIs on a 5-minute sync is available (DOWDP-BM) for DOW6 and DOW7.

Radar	**SR1**	**SR2**	**DOWs 6,7**	**DOW8**	**NOXP**	**MAX**
Polarization	Single	STaR	STSR	Single	STaR	STaR
PRF (Hz)	1500	1500	2000/2500 (Stagger)	2000/2500 (Stagger)	1700/1275 (Stagger)	
Nyquist (m/s)	±20	±20	±80	±80	±40	
Max Range (km)	99	99	60	60	88	
Pulse Length (us)	0.5	0.5	0.4	0.4	0.5	0.4
Gating (m)	75	75	60	60	75	
Sync Minute	5	5	5	5	5	5
Scan Rate (deg/sec)	25	25	50 (PPI) *4 (RHI)*	50	30	30
Num. of Tilts	18	18	40 OR *26 (PPIs) and 6 (RHIs)*	40	23	23
Angle List	SR-PM1	SR-PM1	DOWDP-PM1 OR *DOWDP-BM*	DOW-PM1	NOXP-PM1	MAX-PM1

9.3.3.2.2 Isolated Bore

Hexagon configuration and baselines same as CI.

For an isolated bore, occurring in the absence of an MCS, we will use CI5 or CI8, as described above. Also, as described above, 2- or 5- minute RHI sequence can be added to the scan strategy, syncing on either 5 or 10 min depending on MST guidance relayed to the MRTs by the MRC .

9.3.3.3 RHI Options

RHIs + PPIs must sync at 5 or 10 min intervals. Also, the MRC in consultation with the MST must specify the center azimuth and azimuthal increments of the RHIs.

Radar	SR1	SR2	DOWs 6,7	DOW8	NOXP	MAX
Polarization	Single	STaR	Dual	Single	STaR	STaR
PRF (Hz)	1500	1500	PFM/PNM/CI (same mode as PPIs in the sync)	PFM/PNM/CI (same mode as PPIs in the sync)	1250/937 (Stagger)	
Nyquist (m/s)	±20	±20			±30	
Max Range (km)	99	99			120	
Pulse Length (us)	0.5	0.5			0.5	
Gating (m)	75	75			75	
Duration (min)	2, 3, or 5	2, 3, or 5	2, 3, or 5	2, 3, or 5	2, 3, or 5	2, 3, or 5
Scan Rate (deg/sec)	4	4	4	4	4	4
Num. of Tilts	6, 9, or 15	6, 9, or 15	6, 9, or 15	6, 9, or 15	6, 9, or 15	6, 9, or 15
Angle List	SR-RHI2 SR-RHI3 SR-RHI5	SR-RHI2 SR-RHI3 SR-RHI5	DOW-RHI2 DOW-RHI3 DOW-RHI5	DOW-RHI2 DOW-RHI3 DOW-RHI5	NOXP-RHI2 NOXP-RHI3 NOXP-RHI5	MAX-RHI2 MAX-RHI3 MAX-RHI5

9.3.3.4 Radar Angle Lists

1. SR Angle Lists

List Name	Type	Angles
SR-PFM	PPI	0.8, 1.5, 2.3, 3.1, 4.0, 5.0, 6.1, 7.3, 8.6, 10.1, 11.8, 13.7, 15.7, 17.9
SR-PNM	PPI	0.8, 1.6, 2.4, 3.2, 4.0, 5.0, 7.0, 9.0, 12.0, 15.0, 18.0, 21.0, 25.0, 29.0, 33.5, 38.0, 43.0, 48.0
SR-CI5	PPI	0.8, 1.5, 2.2, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0
SR-CI8	PPI	0.8, 1.5, 2.2, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0

SR-RHI2	RHI	6 azimuths (pick center and increment)
SR-RHI3	RHI	9 azimuths (pick center and increment)
SR-RHI5	RHI	15 azimuths (pick center and increment)

2. DOW Angle Lists

List Name	Type	Angles
DOW-PFM	PPI	0.5, 0.5, 1, 1.5, 2.3, 3, 4, 5, 6, 7, 8, 10, 12, 14, 16, 18
DOWDP-PNM	PPI	0.5, 0.5, 1, 1.5, 2.3, 3, 4, 5, 6, 8, 10, 12, 0.5, 0.5, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 15, 18, 20, 22, 25, 28, 30, 32, 35, 38, 40, 45, 50 (88, 88)
DOW-PNM	PPI	0.5, 0.5, 1, 1.5, 2.3, 3, 4, 5, 7, 9, 11, 13, 15, 18, 20, 22, 25, 28, 30, 32, 35, 40, 45, 50
DOW-C5	PPI	0.5, 0.5, 1, 1.5, 2.3, 3, 4, 5, 6, 7, 8, 10
DOW-CI8	PPI	00.5, 0.5, 1, 1.5, 2.3, 3, 4, 5, 6, 7, 8, 10
DOWDP-BM	*PPI*	*0.5, 0.5, 1, 1.5, 2.3, 3, 4, 5, 6, 8, 10, 12, 15, 18, 20, 22, 25, 28, 30, 32, 37, 40, 45, 50 (88, 88)*
	RHI	*Centered on line parallel to MCS motion vector (e.g., if motion from 270, then: 250, 260, 270, 280, 290, 300)*
DOW-RHI2	RHI	6 azimuths (pick center and increment)
DOW-RHI3	RHI	9 azimuths (pick center and increment)
DOW-RHI5	RHI	15 azimuths (pick center and increment)

3. NOXP Angle Lists

List Name	Type	Angles
NOXP-PFM	PPI	0.5, 1, 1.5, 2.3, 3, 4, 5, 6, 7, 8, 10, 12, 15, 18
NOXP-PNM	PPI	0.5, 1, 1.5, 2.3, 3, 4, 5, 7, 9, 11, 13, 15, 18, 20, 22, 25, 28, 30, 32, 35, 40, 45, 50
NOXP-CI5	PPI	0.5, 1, 2, 3, 4, 5, 6, 7, 8
NOXP-CI8	PPI	0.5, 1, 2, 3, 4, 5, 6, 7, 8

NOXP-RHI2	RHI	6 azimuths (pick center and increment)
NOXP-RHI3	RHI	9 azimuths (pick center and increment)
NOXP-RHI5	RHI	15 azimuths (pick center and increment)

4. MAX Angle Lists

List Name	Type	Angles
MAX-PFM	PPI	0.5, 1, 1.5, 2.3, 3, 4, 5, 6, 7, 8, 10, 12, 15, 18
MAX-PNM	PPI	0.5, 1, 1.5, 2.3, 3, 4, 5, 7, 9, 11, 13, 15, 18, 20, 22, 25, 28, 30, 32, 35, 40, 45, 50
MAX-CI5	PPI	0.5, 1, 2, 3, 4, 5, 6, 7, 8
MAX-CI8	PPI	0.5, 1, 2, 3, 4, 5, 6, 7, 8
MAX-RHI2	RHI	6 azimuths (pick center and increment)
MAX-RHI3	RHI	9 azimuths (pick center and increment)
MAX-RHI5	RHI	15 azimuths (pick center and increment)

9.3.4 Contingency Plans and Alternate Radar Configurations

9.3.1 DOW Operations and Staffing

9.3.2 SMART-R Operations and Staffing

9.3.3 NOXP Operations and Staffing

9.3.4 MAX Operations and Staffing

9.3.5 Mobile radar siting (Ziegler)

PECAN will rely heavily on the collection of data by a suite of mobile ground-based radars and other vehicle-based sensors. It is critically important that the seven “hexagon” mobile radars (listed in section 9.3) be arranged as closely as permitted by available roads to a hexagon whose width scales with the desired sampling area and resolution. The "radar hexagon" is composed of six radars arranged at nodes on the perimeter of the hexagon and one radar at its center. The constraining hexagonal arrangement of the mobile radars achieves optimal array geometry via well-established over-determined multi-radar wind analysis sampling theory, in turn providing the best overall synthesized vector velocity field accuracy and areal/volume coverage for the duration of each IOP.

Due to the planned operations after dark combined with the large area of the extended PECAN domain and the need to acquire suitable sites in minimum time, it is desirable to have access to a pre-surveyed list of radar parking sites that are verified to be both accessible and as unblocked as possible by nearby terrain, trees, and other obstructions (see e.g., section 5.1.i. on p. 21 of the EDO). These pre-surveyed sites will also be useful for parking mobile sounding systems, mobile PISAs, and other sensors deployed from mobile platforms. The sites are computationally referenced in a manner that implicitly imposes the hexagonal array geometry on a consistent basis that also subdivides the large site database into smaller manageable portions. Due to the high required spatial density of candidate sites over the large PECAN domain area and the impracticality of a human surveying the individual sites, NSSL has conducted a "virtual" or computer-based survey to provide candidate mobile radar sites for the PECAN field phase.

9.3.5.1. Virtual GIS identification of candidate sites and scan blockage imagery

An extensive, spatially dense site list that spans the extended PECAN domain has been generated (e.g., Figs. 9.3.5.1 and 9.3.5.2). The effective PECAN domain area has been slightly expanded in eastern CO, northern NE, and southern SD to allow for possible extended PECAN mobile ground-based operations in the unlikely case of too-infrequent MCSs, CI, or Bore events located inside the core PECAN domain. On the order of ~ 13,000 total candidate sites have been generated following the procedures described below.

The NSSL computer-based analysis has employed ArcView graphic information system (GIS) software to identify the list of candidate sites, utilizing high-resolution terrain and land use data combined with shapefile road data to virtually select candidate sites and to generate custom radar terrain occultation images that help determine which sites have acceptable radar visibility. The following input datasets span the extended PECAN domain to enable the GIS calculations:

- TIGER 2010 Census shapefiles of roads (e.g., primary, secondary, local neighborhood/rural/city street) and urban areas.
- State Dept. of Transportation shapefile data for road condition (paved vs. unpaved).
- 1-arc-second (~ 30 meter) resolution USGS National Elevation Dataset (NED) for CONUS.
- 1-arc-second (~ 30 meter) resolution USGS Land Use Dataset for CONUS from which the coverage of the tree land use category is extracted.

A set of plug-in Python scripts have been written and combined with existing ArcView functions to locate suitable parking sites and perform occultation calculations at each site. The site selection and radar occultation calculations have been implemented via the following steps.

9.3.5.1.1. Identification of candidate sites from road databases

Integrating TIGER 2010 Census and paved-unpaved road data, the combination of paved-paved or paved-unpaved road intersections with widely-spaced points along paved roads are flagged as potential parking sites. Sites are required to be either on or immediately adjacent to paved road surfaces. Thus for example, candidate sites located entirely on unpaved section roads are excluded from consideration for use during PECAN since they would likely become impassible after precipitation. The latitude, longitude, and altitude (m MSL) are included in the data record for each site (Fig. 9.3.5.2).

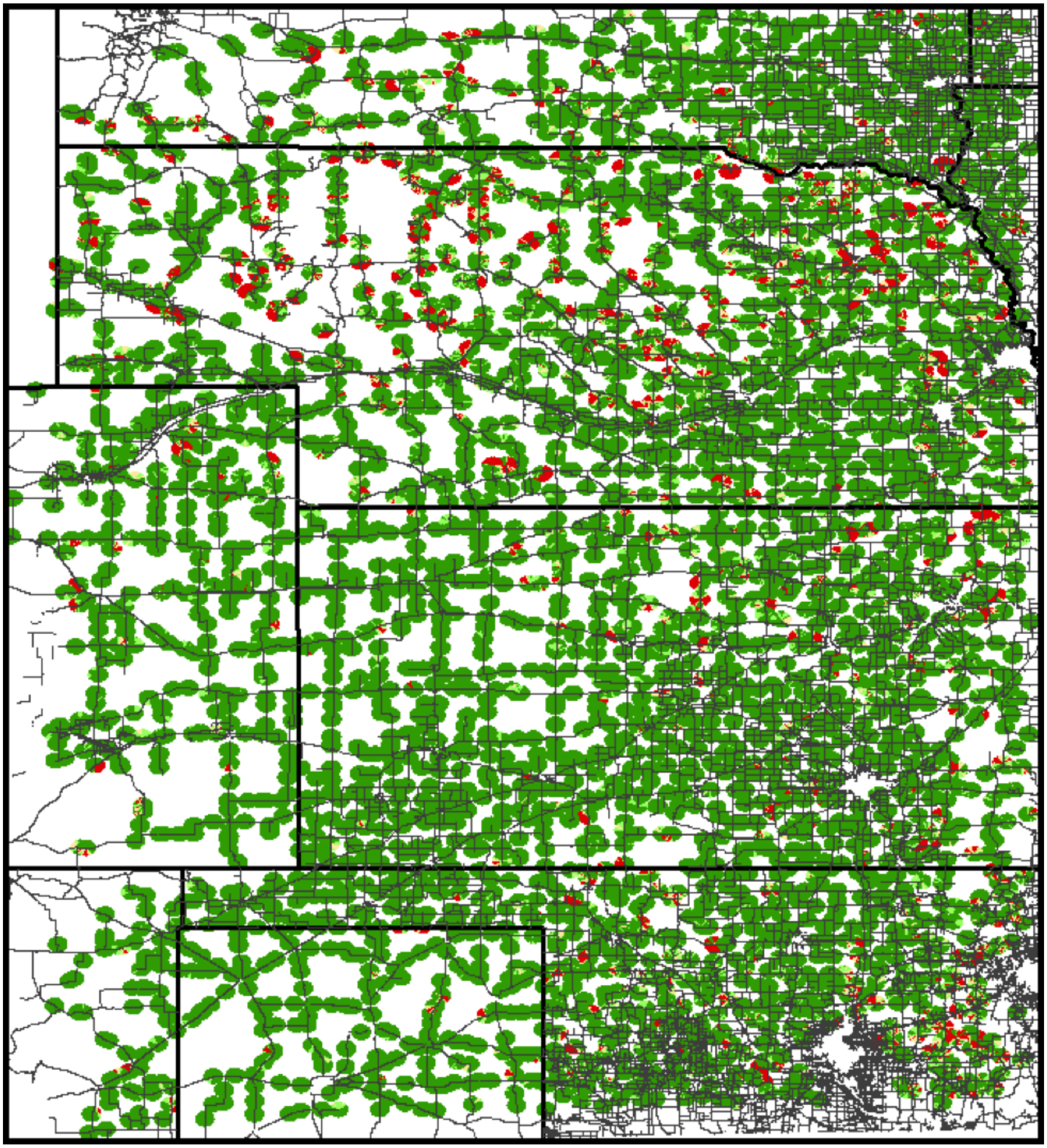


Figure 9.3.5.1. Depiction of the lowest unblocked elevation angle versus azimuth for three low-level sweeps from a "virtual" radar out to ~ 7 km in range at each of over 2,800 "high-quality" sites within the extended PECAN domain. The methods of virtually locating candidate sites and computing radar blockage and the site "quality" are all described in the text. State borders are denoted by heavy black lines, while thin black curves are main paved roads. In this and subsequent figures, the color scale denotes sector blockage extent (dark green = “unblocked at 0.5 deg”, light green = “unblocked at 0.8 deg”, tan = “unblocked at 1.1 deg”, or below those elevations; while red = “blockage at all three elevations”).

9.3.5.1.2. Radar occultation calculation at candidate sites

A radar occultation calculation has been conducted at each of the candidate sites employing a custom Python plug-in script that is executed within ArcView. The ArcView Python plug-in script calculates beam height *h* (km AGL) following eq. 2.28a of Doviak and Zrnic (Academic Press, 1984) as a function of radar beam (centerline) elevation angle θ_e (deg) and arc distance *s* (km) along the ray from zero at the radar, where additionally k_e = 4/3 and *a* = earth radius = 6371 km (Doviak and Zrnic 1984). To gauge the ability to obtain low-altitude radar data at range, the occultation calculations are performed at low elevation angles (0.5, 0.8, 1.1 deg) at 1 deg azimuthal ("ray") and 100 m radial ("gate") increments. For each prescribed site's point coordinate (latitude, longitude) at an assumed 3 m antenna altitude above local ground, the existence of any blocked 100 m ray segment (i.e., a ray segment below ground) is determined by interpolating the local high-resolution terrain height to each 100 m arc-segment along each prescribed ray. It is assumed that all arc-segments at larger ranges than the nearest blocked arc-segment are also blocked.

Two types of geo-referenced 2-D color-filled blockage maps have been produced for each site that display the minimum altitude (km) and the minimum elevation angle (deg) above local ground level of the lowest unblocked gate (e.g., lowest unblocked elevation angle as a function of azimuth and range in Fig. 9.3.5.1).

9.3.5.1.3. Gridding and rank-ordering candidate sites

The extended PECAN domain is spanned by a regular grid mesh with points spaced 15 km apart and staggered to create equilateral-triangular finite grid array elements, and sub-groups of up to five parking sites are assigned to their nearest grid point. Sub-grouping sites according to grid point helps to guarantee that the radar array will be approximately arranged according to the required hexagonal pattern during each IOP. Sub-grouping also conveniently indexes the very large site dataset via a 3-D array with indices (I, J, L), where I and J correspond to the grid point location in the west-east and south-north directions, respectively, and L is the integer rank order of the site from highest (1) to lowest (5).

The parking sites at each grid point are rank-ordered according to a weighted average of weights (see list of weights below) that are proportional to road quality, an estimated blockage at the 0.5 deg base elevation angle, and radial distance from the assigned grid point. The integer values of I, J, and L uniquely identify each site and are included in the data record for that site (Fig. 9.3.5.2), although some grid points do not have any assigned sites. The weighted average of weights combines the following three input weights:

- Road quality index (RQI) with values 1.0 = paved/paved intersection, 0.8 = paved/unpaved intersection, 0.2 = paved road shoulder.
- Annular blockage index (ABI) = 1 - (N_{ba}/30), proportional to the number N_{ba} of 250-m deep range annuli at the virtual 0.5 deg beam elevation containing at least one blocked 30 m x 30 m DEM grid cell (maximum N_{ba} = 30 to radar horizon).
- Radial distance index (RDI) = 1 - (R/R_{max}) where R is the radial distance to the assigned gridpoint, R_{max} spans a grid cell surrounding each grid point, and each site is assigned to one and only one grid point.

N1	N2	N3	N4	N5	NX	NY
2826	2681	2530	2372	2211	48	78

I	J	L	WGT	RQI	ABI	AOI1	AOI2	AOI3	RDI	LAT (deg)	LON (deg)	HGT (m MSL)
0	0	1	0.8194	1.0	1.0000	1.0000	1.0000	1.0000	0.0972	34.794250	-103.777551	1484.657958
0	0	2	0.7915	1.0	0.9333	0.0906				34.822549	-103.742289	1494.605712
0	0	3	0.7693	0.8	1.0000	0.2466				34.808827	-103.775906	1493.475219
0	0	4	0.7541	0.8	1.0000	0.1703				34.794273	-103.795162	1486.733154
0	0	5	0.7427	0.8	1.0000	0.1135				34.808803	-103.757007	1489.469116
•												
•												
•												
28	21	1	0.7887	0.8	1.0000	1.0000	1.0000	1.0000	0.3437	37.527816	-99.320685	704.773681
28	21	2	0.7548	0.8	0.9667	0.2408				37.542482	-99.320931	698.050415
28	21	3	0.7490	0.8	1.0000	0.1452				37.494000	-99.461953	732.783630
28	21	4	0.7448	0.8	1.0000	0.1241				37.454649	-99.320510	694.167236
28	21	5	0.6007	0.8	0.5000	0.4037				37.498394	-99.320184	681.280273

Figure 9.3.5.2. Short excerpt of records from the ASCII site data set showing (from top to bottom, black characters): (a) the header record; (b) the first five site records, that are assigned to the lower-left corner grid point with indices (I, J) = (0, 0); and (c) the five site records corresponding to grid point (28, 21) located near Greensburg in southwest KS. Red lettering denotes the following variables by column: (a) N1-N5 are total numbers of sites in the grid domain ranked one through five respectively, while (NX, NY) are the site grid dimensions in the west-east and south-north directions; (b) I, J, L, WGT, RQI, ABI, AOI1-AOI3, RDI, and HGT are defined in the text, while LAT and LON correspond to the site's latitude and longitude respectively. Note that rank L increases as WGT decreases (i.e., sites are bubble-sorted by WGT at each grid point). Although only the AOI1-AOI3 values for the top-ranked site at each grid point are available at the time of writing, values for the additional sites are in the process of being calculated. The gray fill denotes the record for site (28,21,4) which, although derived purely from the GIS methods discussed in the text, corresponds to the SR1 mobile radar site located 10 miles south of Greensburg KS that was used on 9 June 2009 during VORTEX2.

Any site that either has a value of ABI less than 0.5 or else is within 2 km of an urban area boundary is automatically rejected from further consideration as a candidate site. The values of RQI, ABI, and RDI are included in the data record for each site (Fig. 9.3.5.2). A fourth index called the azimuthal occultation index (AOI) is defined by the expression AOI = 1 - (N_{br}/360), with AOI1-AOI3 defined as in Fig. 9.3.5.2. The parameter N_{br} in the expression for AOI is the number of blocked rays of 1 deg width contained in a 360-deg sweep. The AOI is calculated from the result of the radar occultation calculation previously described in section 9.3.5.1.2. AOI1 is included in a second weighted average of weights, where ABI is replaced by AOI1.

9.3.5.2. Visible imagery at candidate sites

Tests with previously-used VORTEX2 mobile radar parking sites have demonstrated that Google Maps GEO imagery contain information sufficient to broadly characterize the suitability of any given site for parking mobile radars, mobile profilers (PISAs), and mobile sounding vehicles. The radar blockage by terrain and large tree areas having already been objectively quantified via NED and satellite land use data, respectively, and minimized via chosen candidate sites, the presence of any actual fine-scale tree lines or structures in close proximity to the site can easily be identified from GEO. Since most trees or structures in rural areas are typically less than ~ 30 m tall, application of the small angle approximation suggests that they will not significantly block any site with neighboring terrain below ~0.5 deg elevation unless they are within ~ 4 km range. Two GEO images, one at maximum zoom with dimensions of 150 ft x 150 ft and the second with dimensions of 2500 ft x 2500 ft, are sufficient to identify most potential nearby local above-ground blockages from structures or small tree areas.

Google Maps Street View covers many (though not all) roads of interest in the extended PECAN domain. The combination of the two GEO images with Street View images to the north, east, south, and west (for those locations having Street View) visually characterize each site. The likely ability to supplement GEO images with Street View images allows the user to confirm certain details inferred from the GEO Birds-eye zoom image; namely the width of shoulders and aprons (parking space), the type of pavement, character of bar ditches and surface drainage features, access roads to private property, power poles and lines, proximate trees and/or structures, etc. Thus although Google Maps GEO imagery is deemed necessary and sufficient, the combined access to Google Maps GEO and Street View imagery would enhance robustness.

9.3.5.3. Utilizing virtual site data in the Operations Center and in mobile platforms

The complete parking site data set (other than visual imagery) and the site reference grid is compact enough to be viewable either within Catalog Maps via the PECAN Field Catalog or inside a mobile ground-based vehicle via a web browser application. As previously discussed in section 9.3.5.2, low-bandwidth visual imagery could be downloaded either via landlines (Operations Center) or cellular Internet connections (mobiles).

Google Maps images may be generated on demand during PECAN for any given site based on the prescribed input coordinates of that site (e.g., latitude, longitude). NSSL has developed simple scripts to access Google Maps imagery using the Google Maps Static Application Program Interface (API) and Google Maps Street View Image API via any web browser. (After carefully considering terms-of-use, NSSL has decided to generate low-bandwidth imagery on demand using API functions via the Internet rather than mass-archiving images of Google Maps content.) Downloaded images are roughly ~30 kilobytes in size, thus requiring fairly small bandwidth suitable even for many rural environments that often have reduced cellular Internet or voice bandwidth. Image size may be increased for PECAN field catalog display (particularly those generated at the Operations Center which will enjoy high dedicated bandwidth), though likely requiring only limited increase in bandwidth.

Due to the large total number of sites, it is prudent to restrict domain-scale viewing of site locations and radar scan images (e.g., Fig. 9.3.5.1). For example, all sites of a given rank within the chosen radar hexagon location could be viewed by the radar coordinator at the Operations Center), while up to five sites surrounding an assigned grid point could be selected by a given mobile radar field leader. The AOI1 and ABI value should be considered together (with the AOI1 value given greatest weight) in comparing closely-spaced adjacent sites (e.g., Fig. 9.3.5.3) to help determine which is the best site in an overall radar-visibility sense. Clear, detailed viewing of individual sites requires zooming the display to focus only on smaller features such as the intended deployment area for the mobile ground-based radar hexagon array (Fig. 9.3.5.3). The field of geo-referenced 2-D color-filled blockage maps may be visually perused to quickly estimate the suitability of a site(s) or area according to degree of blockage. If the top-ranked site at a given grid point is deemed unsuitable for any reason,

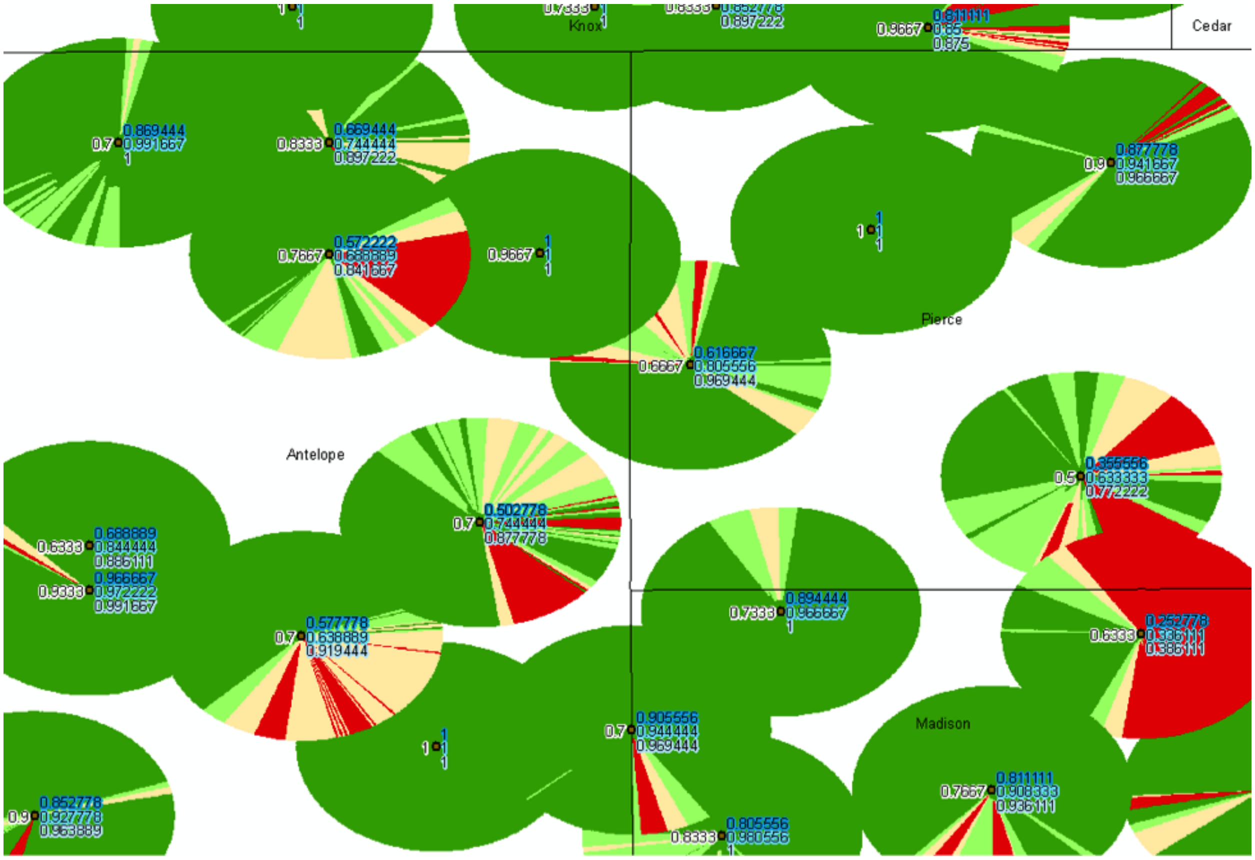


Figure 9.3.5.3. As in Fig. 9.3.5.1, but showing lowest unblocked elevation angle from each 1st-rank site (NOTE: based on ABI) within the area of Pierce, Antelope, and Madison counties in northeastern NE. Black circles denote parking site locations, while the color fill again denotes blockage extents at the 0.5, 0.8, and 1.1 deg elevation angles. The numbers to the left and right of each site are the ABI value and the three AOI values corresponding to the 0.5, 0.8, and 1.1 deg elevations respectively. Since ABI and AOI each measure blockage but are derived quite differently, they broadly tend to be linearly correlated in a least squares sense (not shown). A strongly blocked sector appearing to emanate from a site (e.g., the severely blocked eastern sector at the southeastern site) is typically caused by tree or terrain blockage in that sector that is in close proximity to that site. The latter may be verified by examining the site using Google Maps imagery. Terrain blockage is typically experienced within ~ 7 km range and within the first ~ 1 deg of elevation at any given site in the extended PECAN domain, although closer and deeper blockages are occasionally detected in the calculations.

the approximate hexagon radar configuration should be preserved by alternately choosing the next closest-ranked site at that grid point (and so on). To maintain adequate spacing between the radars while preserving the approximate hexagonal array geometry, the appropriate scale of grid pattern should be chosen to maintain the approximate grid point spacing of the nominal hexagon that is desired for a given IOP (e.g., ~ 30 km for MCS mission either with or without Bore sampling, and ~ 15 km for clear-air CI or pure Bore missions).

Visual imagery to characterize individual sites will be provided using Google Maps API functions during PECAN. Two optional applications will be available for perusing selected on-demand Google Maps images:

• *Integration with the Field Catalog in high-dedicated-bandwidth conditions (e.g., Operations Center).* From Catalog Maps in the Field Catalog, display markers would designate the location points of the radar parking sites. Clicking on each site marker would access a script on an EOL server that generates pop-up listings of up to six available Google images: two top-down GEO or "birds-eye" views of the site (maximum zoom and a "horizon" zoom) and four Street View images for N-E-S-W views (each with 120 degree field-of-view). Clicking to select a given Google image would run the appropriate Google API script on an EOL server, and the the generated image would open as a tab in the Catalog Maps display. Note for example that the Radar Coordinator would usually select appropriate parking sites for the individual mobile radars, and subsequently transmit that site coordinate information and any brief deployment instructions via a GEO-satellite service such as DeLorme Inreach Explorer.

• *Viewing sites in low-bandwidth conditions (e.g., mobile platforms).* On client computer or Smart-phone running a browser, mobile users could select a URL to access a simple webpage on a remote NSSL host server that allows the user to select and display low-bandwidth images (~ 30 kilobytes) in the browser window. User enters the site's (I, J, L) locator indices or the specific site coordinates, and requests images to display in the browser window. To offer extra potential bandwidth savings, the user may pre-select which images to download for viewing. Another handy NSSL script allows the mobile user to find the ten nearest mobile sites relative to either the current location or else the location of the platform's target gridpoint. One of the NSSL browser scripts includes a handy "radar hexagon tool", that illustrates how the Catalog Maps user could overlay the tool on the displayed site map and manipulate the hexagon template to help find good sites in proximity to the hexagon's center and node points.

The operational parameters governing the total demand placed by the EOL or NSSL servers on the two Google APIs (Google Street View Image API and Google Static Maps API) should be carefully noted by PECAN coordinators and other PECAN users. The following are the limits for each API as set by Google:

- *25,000 requests per webpage per day*;
- *1,000 requests per IP address (read: individual computer) per day*;
- *50 requests per IP address per minute*;

The biggest user of the Google APIs is the main explorer page employed by the coordinators in Hays. A single request-for-images makes a total of up to two (2) Google Static Maps images and four (4) Google Street View images, hence the largest "unit usage" of the two APIs is four (4) images. In other words, a single computer could examine 250 candidate sites during a given IOP (i.e., 36 sites per mobile hexagon radar assuming 7 radars) and not exceed the limit for any individual computer (1,000). The latter assumed 1,000 hits is negligible compared to the webpage limit of 25,000 maximum hits per IOP. Hence, e.g., doubling or tripling the number of computers exploring sites only totals up to 750 sites (only 3,000 hits against the limit of 25,000). Since mobile users can and should self-impose use limits (only pulling carefully selected images) and given the limited need for the NSSL web pages by the mobile users owing to dependence on PECAN coordinators (who will access the EOL server via Catalog maps), it is expected that total use by the main PECAN-EOL explorer page will strongly dominate over total NSSL mobile use.

An NCAR/EOL-maintained archive of the radar parking site text and scan blockage map image data files describing the full list of candidate sites (i.e., the "site dataset") would be useful for several reasons. Such an archive would facilitate the integration of the site dataset with the capability to browse visual Google Maps images using the on-demand, NSSL-provided API scripts via the PECAN Catalog Maps display system. The Catalog Maps display is intended to serve as a standard situational awareness tool for PECAN, and access to the site dataset by all PECAN teams is key. NSSL has provided EOL with copies of the dataset, thus facilitating access to the EOL archive by the enhanced Catalog Maps display during PECAN. The EOL archive would also provide a convenient mechanism for PECAN participants to download the site dataset to help prepare their individual mobile facilities for the field phase.

10. Mobile Ground-based In Situ Platform Operations (Coniglio/Wurman/Ziegler)

(Michael Coniglio, Matthew Parker, Russ Schumacher, Karen Kosiba, Conrad Ziegler)

10.1 Operations Overview

An integral part of PECAN will be the collection of data by a suite of mobile ground-based in situ observing systems. The plan detailed below outlines the strategies for three vehicles equipped with balloon-borne rawinsonde sounding systems (mobile GPS advanced upper-air sounding systems, or MGAUSs). The MGAUS vehicles (two provided by NSSL and one by CSU) will also be equipped with roof-mounted instruments to measure temperature, pressure, humidity, and winds at 1 Hz ("mobile mesonet" systems). Another five vehicles will be equipped only with mobile mesonet systems and are known as "mobile mesonets" (MMs). Two of the MMs are provided by NSSL and three additional MMs will be provided by CSWR. Up to 10 instrumented "Pods" will be ground-deployed from the CSWR MM vehicles. The deployment diagrams in the following sub-sections presume the existence of paved roads that approximate the conceptualized MM deployment patterns. Data collected by the MGAUS and NSSL MMs will help to 1) characterize the transition from surface-based to elevated nocturnal MCS structure and the interaction of cold pools generated by MCSs with the nocturnal SBL, and 2) determine how the organization and evolution of surface-based and elevated MCSs are influenced by the stable boundary layer and the vertical profile of wind and stability above the nocturnal low-level jet (NLLJ).

Each MGAUS will use Vaisala RS92G sondes with a ground system consisting of a receiver and a ground check system for conditioning the sondes. The system uses a roof-mounted GPS antenna for wind finding and a UHF antenna operating around 400 Hz for transmitting the signal from the sonde to the ground system. A laptop computer running software will be used to process the rawinsonde data. A single, typical radiosonde observation employing a 200-gram balloon (balloon flight to at least the tropopause) can be completed in roughly 60 minutes (not including ~10 minutes for sonde preparation and balloon inflation). All MGAUSs will be capable of radiosonde reception from a moving vehicle (and hence using a moving system receiver), which will allow for highly mobile strategies for sampling the MCS and the environment. Further details on the general configuration of the Vaisala receiver and sonde specifications can be found here: https://www.eol.ucar.edu/instrumentation/sounding/gaus.

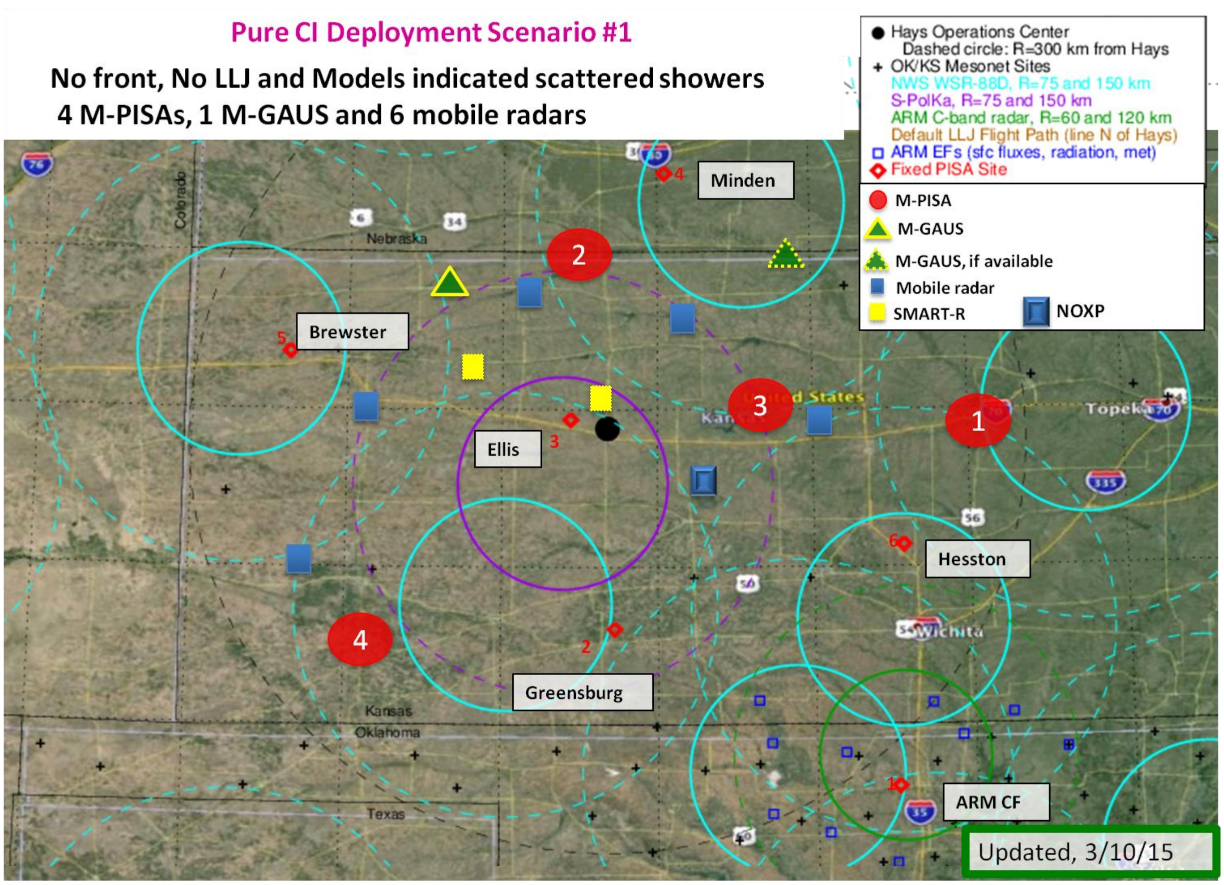
10.2 Sampling Strategies

All observing strategies with the mobile in-situ observing systems will be conducted within the area covered by at least dual-Doppler coverage by two or more of the mobile radars. For MCS missions, the goal is to take advantage of the high mobility of the MGAUSs and MMs to target large meso-γ to small meso-β-scale portions of the MCS convective line (CL) and associated trailing or adjoining stratiform precipitation that may not be sampled by the PISAs. For CI and Bore missions, the MGAUS and MMs will supplement the meso- β-scale sampling of the PISAs with finer spatial scale observations in the center of the mobile radar array. The observing strategy for a given IOP will depend on the mission type (MCS, CI, or Bore).

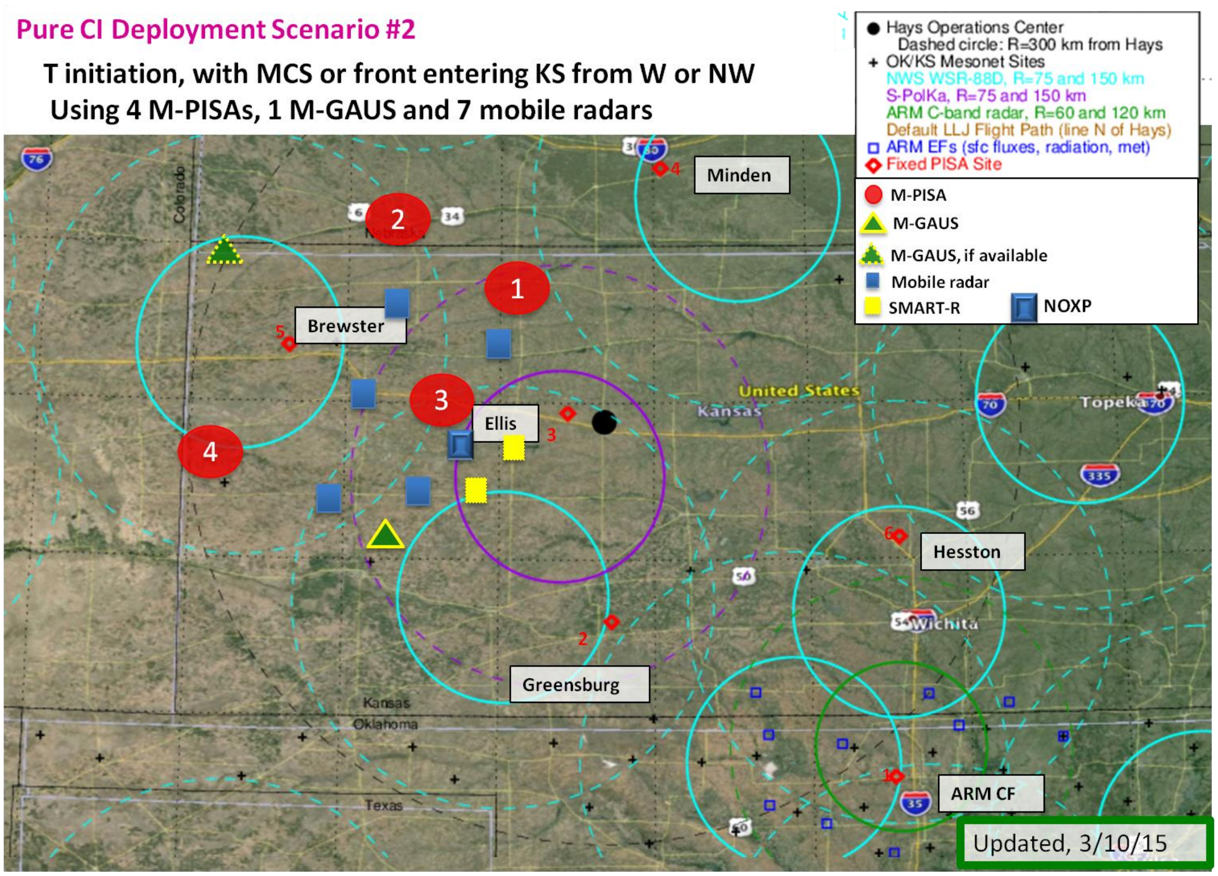
a. CI missions

The general deployment strategies for the CI missions are shown below.

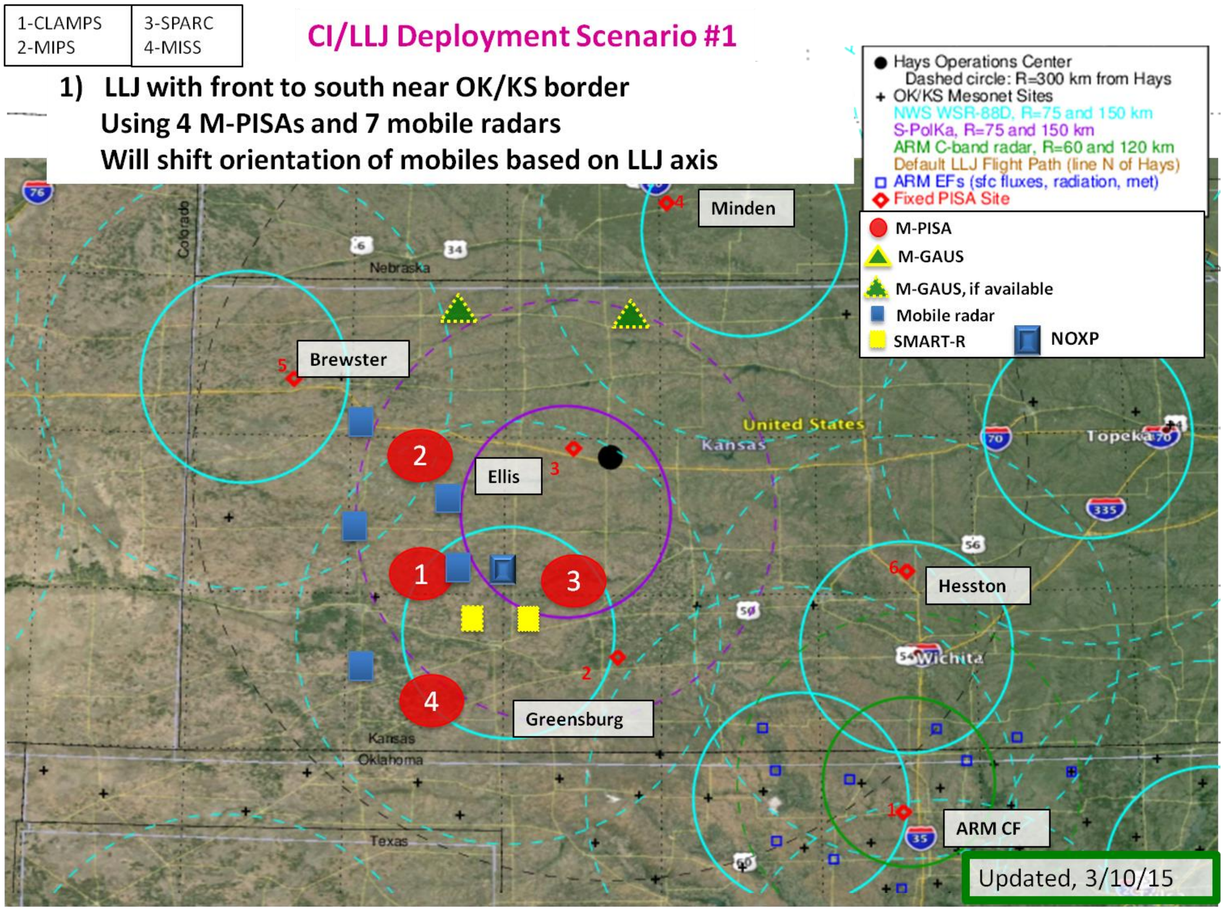
This is the scenario for the CI mission in the forecast of scattered showers with no front and no nocturnal LLJ. This mission would occur with soundings nominally at 03 and 06 UTC.



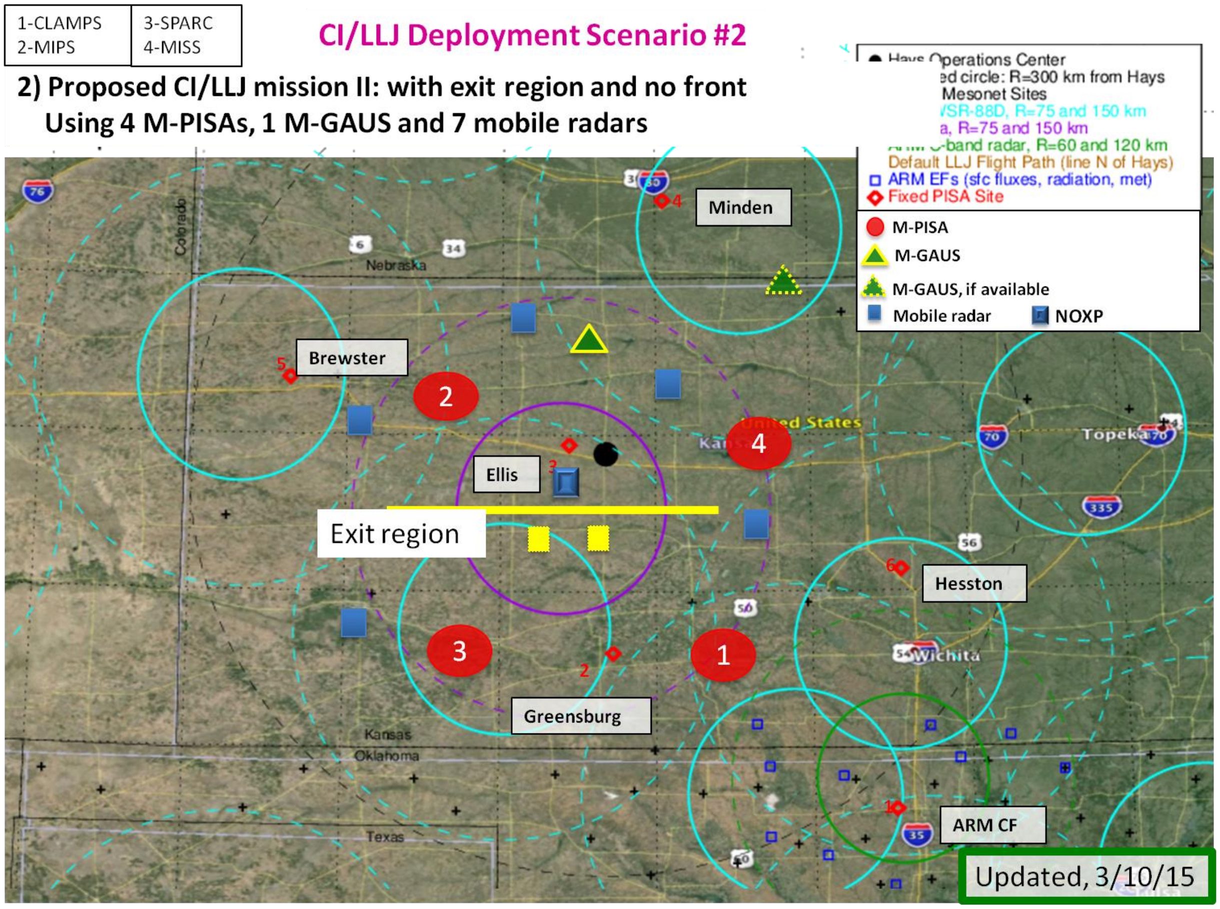
This is the scenario for the CI mission in the forecast of "T initiation" with an MCS or front entering Kansas from the west or northwest.. This mission would occur with soundings nominally at 03 and 06 UTC.



This is the scenario for a combined CI/LLJ mission with a forecast of convection associated with a LLJ and a stationary front. This mission would occur with soundings nominally at 00, 0130, 03, 06 and 09 UTC.



This is the scenario for a combined CI/LLJ mission with a forecast of convection associated with a LLJ with no stationary front. This mission would occur with soundings nominally at 00, 0130, 03, 06 and 09 UTC.



b. Bore missions

The general deployment strategies for the Bore missions are under development and waiting input from the Bore teams. It is expected that no more than two sondes per MGAUS will be launched in both the CI and Bore missions and only one or two MGAUS vehicles will be deployed for these missions.

c. MCS missions

There are four unique strategies for sampling MCSs depending on the expected MCS structure, evolution, and speed of motion and are denoted. The MCS-A, MCS-B, and MCS-C strategies apply to leading-line/trailing-stratiform (LL/TS), parallel stratiform (PS), and leading stratiform (LS) MCS structures. The MCS-D strategy applies to training-line/adjoining-stratiform (TL/AS) MCSs. The former MCS modes collectively are expected to account for most of the MCS cases during PECAN.

Sonde usage for MCS missions will be more than in the CI and Bore missions. The strategies below will require approximately 6-8 sondes per MGAUS to complete the mission.

(1) MCS-A

The MCS-A strategy is to sample with all MGAUSs co-located and with a launch frequency of ~20 minutes staggered between the three MGAUSs. The distance ahead of the convective line (CL) where sampling commences will vary by case but will generally be in a location that allows for ~2 h of sampling in the environment before the CL reaches the MGAUSs location. THe MGAUSs may reposition toward the CL after each launching if the line is moving slow (~ < 15 kt) and may reposition away from the CL after launching if the MCS is moving fast (~ > 35 kt). This strategy is designed to sample an MCS at high temporal resolution from a fixed location to maximize the resolution of analyses generated from time-to-space converted sounding data in a 2D (x-z) cross section. This strategy assumes stationarity to the system and is best used when there aren't large asymmetries to the CL or MCS structure. The mobile mesonets (MMs) will perform ~40 km long opposing transects perpendicular to the approaching CL with the MGAUSs as the center point. These measurements will provide validation of the time-to-space corrected data at the surface.

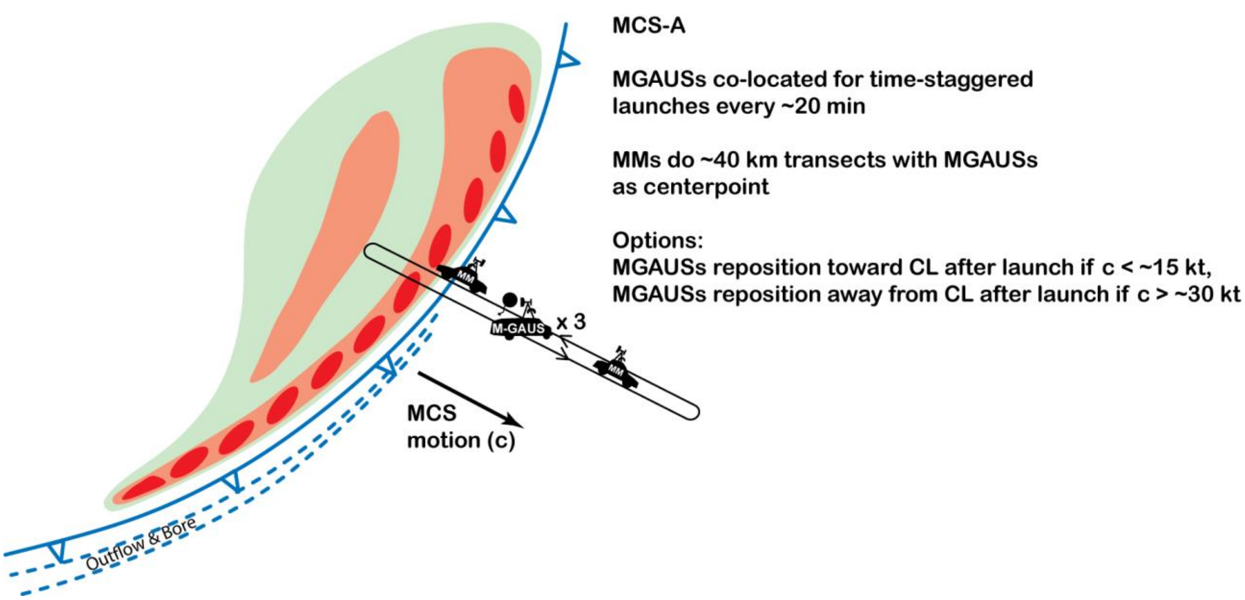


Figure 10.2.3. "MCS-A" deployment of MGAUS and MM platforms. Note emerging bore wave on southern extent of outflow boundary.

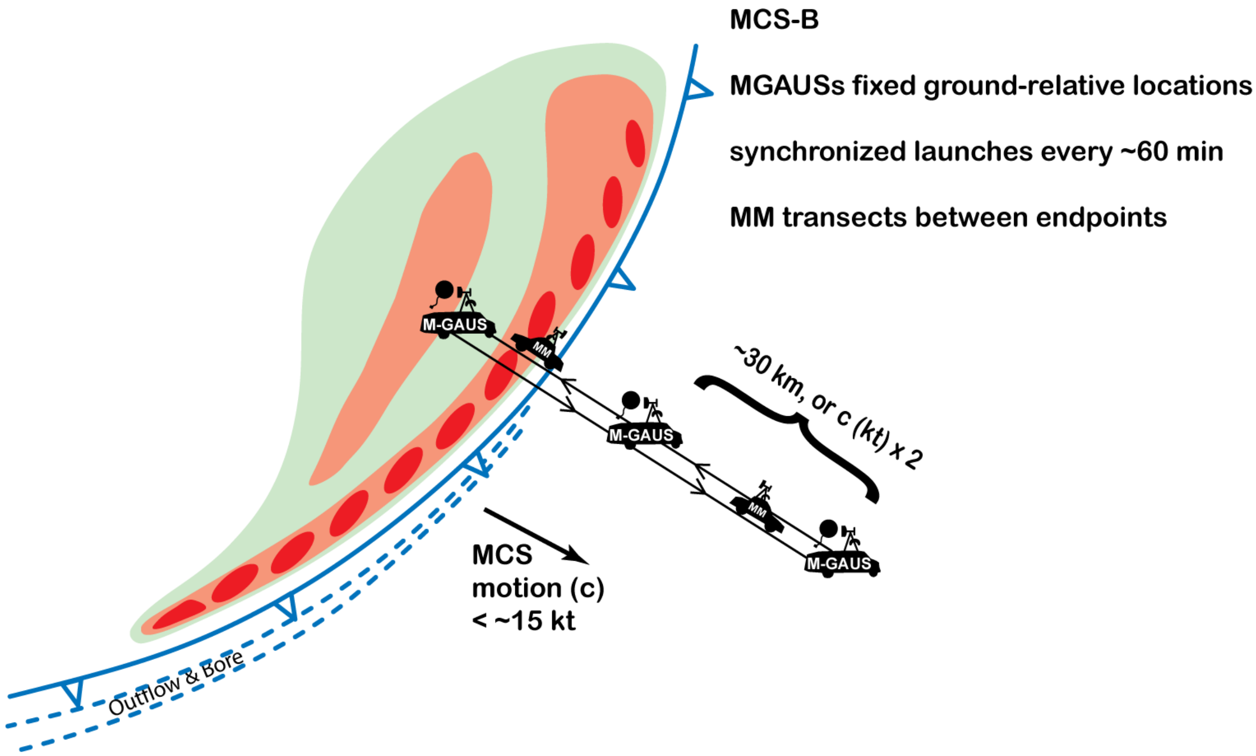


Figure 10.2.4. "MCS-B" deployment of MGAUS and MM platforms. Note emerging bore wave on southern extent of outflow boundary.

(2) MCS-B

The MCS-B strategy is designed to sample an MCS at high temporal resolution from three different fixed locations and only applies to slow moving MCSs (~ < 15 kt). Each MGAUS will launch every 60 minutes with the launches synchronized. Launches should begin ahead of the CL with enough time to allow for at least six environmental soundings (at least two from each team). The mobile mesonets (MMs) will perform ~40 km long opposing transects perpendicular to the approaching CL with the MGAUSs as the end points. These measurements will provide validation of the time-to-space corrected data at the surface.

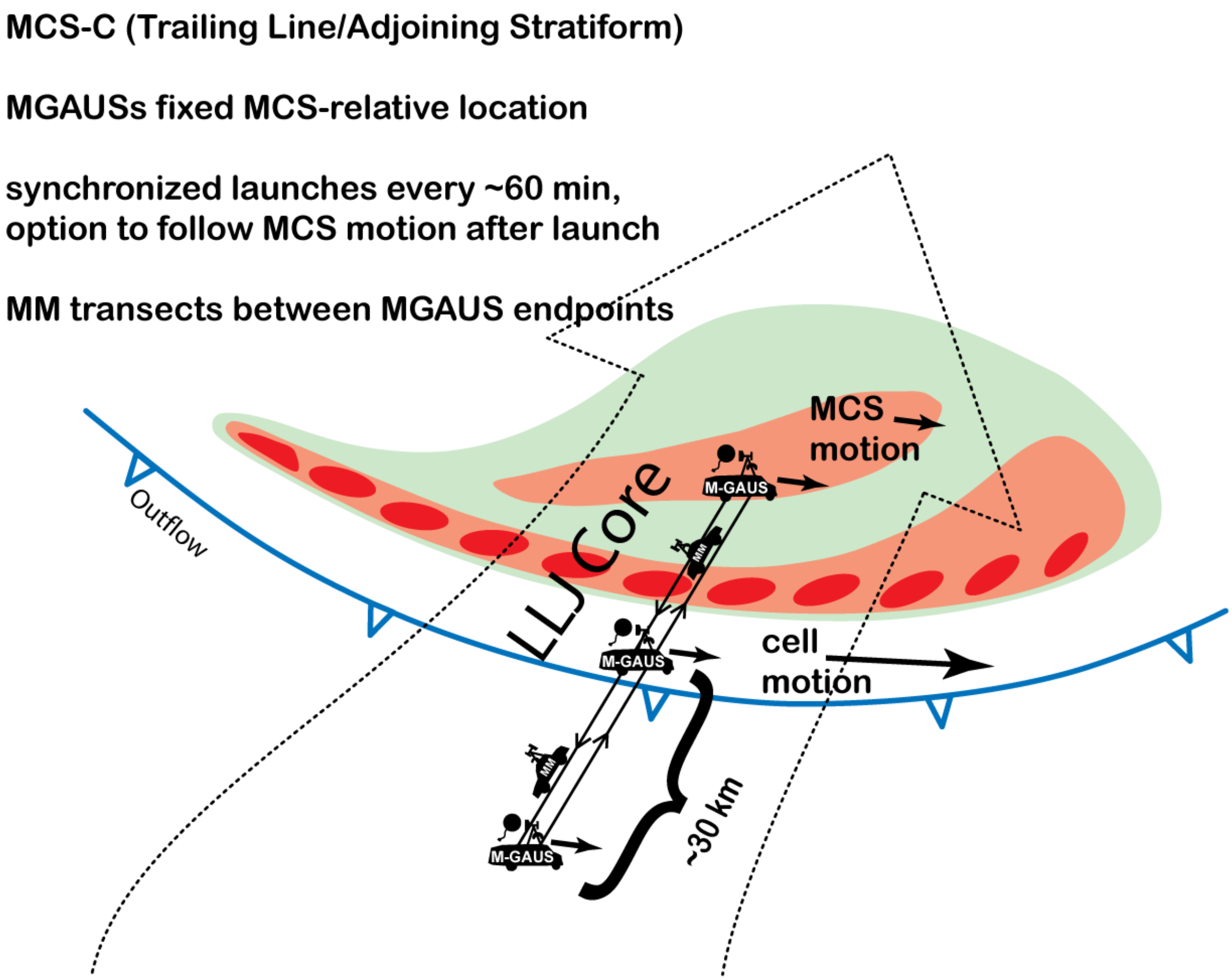


Figure 10.2.5. "MCS-c" deployment of MGAUS and MM platforms. Note emerging bore wave on southern extent of outflow boundary.

(3) MCS-C

The MCS-C strategy will be used for slow-moving or stationary Trailing Line/Adjoining Stratiform (TL/AS) MCSs in which the angle between the CL and the MCS motion vector is small. The goal is to sample how the SBL structure interacts with the MCS outflow along an axis parallel to the NLLJ, which is presumably the main source of forced lifting for the maintenance of the MCS. Launches will be made every 60 minutes with the MGAUSs maintaining their MCS-relative position throughout the IOP and spaced ~ 30 km apart. The MMs will do transects between the MGAUS endpoints.

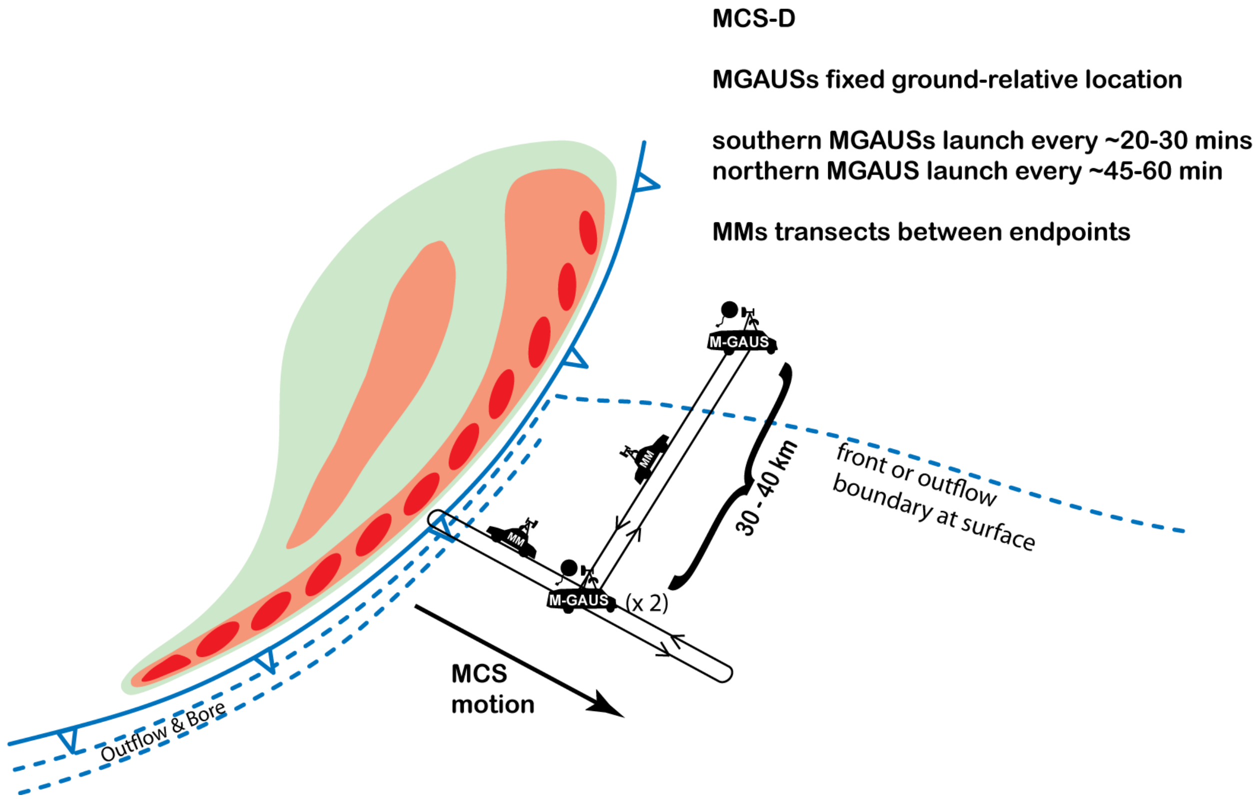


Figure 10.2.6. "MCS-D" deployment of MGAUS and MM platforms. Note emerging bore wave on southern extent of outflow boundary and the location of the front or outflow boundary at the surface.

(4) MCS-D

The MCS-D strategy is designed for the special case of an MCS bisecting a mesoscale or synoptic-scale frontal boundary, in which there is likely to be horizontal variability in instability and environmental shear in the along-CL direction. Two MGAUSs will be co-located and launch every 20-30 minutes staggered in time. The third MGAUS will position 30-40 km away from the other MGAUSs in a direction parallel to the CL toward the northern end of the system and to the north of the front or outflow boundary. There will be the option to cut off the reception of the transponder from each sonde after ~45 minutes to allow for more rapid launches while still sampling most, if not all, of the troposphere. The cut-off time can be programmed in the ground station prior to launching the sonde. The MMs will do transects between the MGAUS endpoints.

11. Operational Data (Williams)

11.1 Surface Meteorological Data

11.2 Precipitation Data

11.3 Radar Data

11.4 Streamflow Data

11.5 Flux Data

11.6 Soil Temperature and Soil Moisture Data

11.7 Upper Air Data

11.8 Composite Radar Data Sets

11.8.1 NSSL (QC and non-QC) WSR-88D real-time radar composites (Ziegler)

11.8.2 NCAR WSR-88D + S-Pol radar composite (Weckwerth)

PECAN Radar Mosaics
PECAN radar mosaics will be created in real-time and will include the Level II data from the following radars:

- Cheyenne, WY (CYS)
- Denver, CO (FTG)
- PUX (Pueblo, CO)
- North Platte, NE (LNX)
- Goodland, KS (GLD)
- Dodge City, KS (DDC)
- Amarillo, TX (AMA)
- Omaha, NE (OAX)
- Hastings, NE (UEX)
- Topeka, KS (TWX)
- Wichita, KS (ICT)
- Vance Air Force Base, OK (VNX)
- Tulsa, OK (INX)
- Oklahoma City, OK (TLX)
- S-Pol, located ~40 km SW of Hays, KS at Latitude: 38° 33’ 12.6”N; Longitude: 99° 32’ 9.9” W; Elevation: 2149 ft ASL

2-D mosaics will be created by NCAR/EOL:

1) There will be a low-level 2-D mosaic gridded at $\Delta x = \Delta y = 250$ m showing the fields of reflectivity (Z), radial velocity (V), spectrum width (SW), differential reflectivity (ZDR) and correlation coefficient (Rho-HV). This will provide high-resolution, high-sensitivity data to monitor low-level bores and clear-air features. These fields will be viewable in CIDD and/or Jazz and will be in the Field Catalog.

2) There will be a QPE mosaic gridded at $\Delta x = \Delta y = 500$ m showing rain rate and rainfall accumulation. This will be viewable in CIDD and/or Jazz and in the Field Catalog.

3-D mosaics will be created by NCAR/EOL:

1) There will be a 3-D mosaic gridded at $\Delta x = \Delta y = \Delta z = 500$ m showing the fields of reflectivity (Z), spectrum width (SW), differential reflectivity (ZDR), correlation coefficient (Rho-HV), differential phase (KDP), particle identification (PID) and QPE. Radial velocity will not be included in this 3D mosaic field. These fields will be viewable in CIDD and/or Jazz and the Field Catalog.

These 3-D polar radar data fields will be obtained by NCAR/EOL:

1) Full volume polar data from each of the individual radars listed above will be available for individual radar viewing. This will have the fields of reflectivity (Z), radial velocity (V), spectrum width (SW), differential reflectivity (ZDR), correlation coefficient (Rho-HV), differential phase (KDP) and particle identification (PID). The QPE fields will be provided for the lowest scans only. The ARM CF and mobile radars may be available These fields will be displayed in CIDD and/or Jazz and the Field Catalog.

2) If readily available in real-time, the ARM CF and PECAN mobile radars may also be available for viewing in CIDD and/or Jazz.

NOAA mosaics

The NOAA mosaic product is available in real-time for a larger view than these PECAN mosaics will provide. You can access that by pointing your browser to mrms.ou.edu. There are many 3-D products but these instructions take you to a set of 2-D clear-air products. The QC'ed reflectivity products are 3-D. Select "Single Product Maps". Select "Submit/Refresh" button in upper left. To zoom, drag a box in the region selection at left (repeat to select a different sub-region, or "Reset Region" to go back to CONUS. From the root URL, there are tutorials under e.g., "Legacy 2012 QVS".

11.9 Satellite Data (examples as of IHOP, so needs updating)

11.9.1 Geostationary Operational Environmental Satellite (GOES)

11.9.2 Polar Orbiting Environmental Satellite (POES)

11.9.3 Defense Meteorological Satellite Program (DMSP)

11.9.4 Terra/Aqua

11.9.5 NESDIS/ARAD

12. Forecasting (Gallus)

12.1 Forecast Support Plans

Forecasting throughout the project will be provided by a team of expert forecasters assisted by a team of graduate students. The experts will include William Gallus from Iowa State University, Stan Trier from NCAR, and David Imy and Jack Hales, retired from SPC. Two experts will assist with forecasting on most days, although on some days, only one expert will be available as the other serves as expert nowcaster (see details below). Two or three graduate students will be present at all times, with 1 or 2 assisting the forecasting efforts.

The expert forecaster(s) and student assistants will work a roughly 8 am through 5 pm shift. Primary responsibilities for the forecasters will include:

a. conducting a teleconference at 9:30 am with NWS offices on days where significant convective activity is anticipated in the CWAs of those offices
b. providing a preliminary day 1 forecast by 11:30 am which will include a probability forecast (Low, Moderate, High) for MCS activity during the 00-12 UTC period, a similar forecast for bores, and a similar forecast for pristine elevated nocturnal convective initiation (CI). Important boundaries and expected location and peak time of the low-level jet (LLJ) will be shown on the MCS forecast map.
c. holding the main weather briefing at 3 pm where day 1, 2 and 3 forecasts will be presented. MCS forecasts (similar to the preliminary forecast) for Day 1 will be performed for every 3 hour period beginning with a 3 hour period centered on the most likely time of initiation of an MCS. Bore forecasts will be provided for 00-06 UTC and 06-12 UTC, along with forecasts of pristine CI for the same periods. For Days 2 and 3, a single forecast spanning 00-12 UTC will be made for each of the 3 weather parameters (MCSs, bores, CI), again using the same probability categories.
d. discussing forecasting issues with the incoming nowcast team after the 3 pm briefing
e. an evening Day 2 update will be issued by the nowcast team (see below)

12.2 Nowcast Support Plans

The same 4 expert forecasters, along with David Blanchard, retired from NWS, will provide nowcasting support, working a roughly 3 pm through midnight shift. Nowcasts will only be needed during IOPs, or roughly 20 days at most during the project. One expert nowcaster will be on duty, accompanied by 1-2 student assistants. Nowcasters ideally will be present for the 3pm briefing, and will then be briefed as necessary by the forecast team prior to the end of their shift. Nowcasters will provide current updates on weather conditions throughout their shift, and will also be responsible for providing a day 2 updated forecast by 10 pm, which will provide similar forecasts for Day 2 to those made in the preliminary Day 1 forecast.

12.3 Real-Time Numerical Modeling Plans

It is anticipated that several convection-allowing model runs will be made in real time and used by the forecasting team. These will likely include the NSSL WRF, a WRF run from Russ Schumacher at Colorado State University, possibly an ensemble run by CAPS, and a WRF run by Xuguang Wang at the University of Oklahoma. In addition, operational high resolution runs from the HRRR and NMMB (and possibly other models) should be available to the team. For at least one or two of these models, it is anticipated that some new bore parameters will be output for use by the forecasters (most likely the NSSL WRF and HRRR). This list of models is likely not exhaustive, and the forecast team will consider other convection-allowing runs that may be made available in real time.

13. Data and Information Management (Williams)

13.1 Data Policy

13.2 Data sharing in the field

13.3 On-line field Catalog (Stossmeister)

13.4 Data Management Plans

13.5 Data Archive and Access

14. Education and Outreach (Rauber)

15. Reports, Presentations and Scientific Papers Archive

16. Appendices

A. Scientific Steering Committee (Geerts)

Belay Demoz, Howard U.
Rich Ferrare, NASA Langley
Bart Geerts, U. Wyoming

John Hanesiak, U. Manitoba
Kevin Knupp, U. Alabama
Matthew Parker, N. Carolina State U.
David B. Parsons, U. Oklahoma
Robert Rauber, U. Illinois
Xuguang Wang, U. Oklahoma
Tammy M. Weckwerth, NCAR
Josh Wurman, CSWR
Conrad Ziegler, NSSL

B. Mission Selection Team roster (Geerts)

	Chair	Ops Director	UWKA FS	P-3 flt scientist	DC-8 FS	MCS science	Bore science	CI science	LLJ science	M radars	soundings	MP rep	S-POL + FP	forecast leader
31-May	Parsons	Salazar	Geerts			Ziegler/ Biggerstaff	Koch	Weckwerth	Geerts	Wurman	Parker	Turner	Weckwerth	Bill Gallus
1-Jun	Parsons	Salazar	Geerts			Ziegler/ Biggerstaff	Koch	Weckwerth	Geerts	Wurman	Parker	Turner	Weckwerth	Bill Gallus
2-Jun	Parsons	Salazar	Geerts			Ziegler/ Biggerstaff	Koch	Weckwerth	Parish	Wurman	Parker	Turer	Weckwerth	Bill Gallus
3-Jun	Parsons	Salazar	Geerts			Ziegler/ Biggerstaff	Koch	Weckwerth	Parish	Wurman	Parker	Turner	Weckwerth	Bill Gallus
4-Jun	Parsons	Salazar	Geerts			Ziegler/ Biggerstaff	Koch	Weckwerth	Parish	Wurman	Parker	Turner	Weckwerth	Bill Gallus
5-Jun	Parsons	Salazar	Geerts			Ziegler/ Biggerstaff	Koch	Weckwerth	Parish	Wurman	Parker	Turner	Weckwerth	Bill Gallus
6-Jun	Parsons	Salazar	Geerts			Ziegler/ Biggerstaff	Koch	Weckwerth	Parish	Wurman	Parker	Turner	Weckwerth	Bill Gallus
7-Jun	Parsons	Salazar	Geerts			Ziegler/ Biggerstaff	Knupp	Weckwerth	Shapiro	Wurman	Parker	Bonin	Weckwerth	Bill Gallus
8-Jun	Parsons	Salazar	Geerts			Ziegler/ Biggerstaff	Knupp	Weckwerth	Shapiro	Wurman	Parker	Bonin	Weckwerth	Bill Gallus
9-Jun	Parsons	Salazar	Geerts			Ziegler/ Biggerstaff	Knupp	Weckwerth	Shapiro	Wurman	Parker	Bonin	Weckwerth	Bill Gallus
10-Jun	Weckwert h	Salazar	Geerts			Ziegler/ Biggerstaff	Knupp	Wilson	Shapiro	Wurman	Parker	Feltz	Wilson	Bill Gallus
11-Jun	Weckwert h	Salazar	Geerts			Coniglio	Knupp	Wilson	Shapiro	Wurman	Coniglio	Feltz	Wilson	Bill Gallus
12-Jun	Weckwert h	Salazar	Geerts			Coniglio	Knupp	Wilson	Shapiro	Wurman	Coniglio	Feltz	Wilson	Bill Gallus

13-Jun	Weckwerth	Salazar	Geerts			Coniglio	Knupp	Wilson	Shapiro	Wurman	Coniglio	Wagner	Wilson	Jack Hales
14-Jun	Weckwerth	Salazar	Parish	Rauber		Coniglio	Knupp	Wilson	Shapiro	Wurman	Coniglio	Wagner	Wilson	Jack Hales
15-Jun	Weckwerth	Salazar	Parish	Rauber		Coniglio	Knupp	Wilson	Chilson	Wurman	Coniglio	Wagner	Clark	Jack Hales
16-Jun	Weckwerth	Salazar	Parish	Rauber		Coniglio	Knupp	Wilson	Chilson	Biggerstaff	Coniglio	Wagner	Clark	Jack Hales
17-Jun	Weckwerth	Salazar	Parish	Rauber		Coniglio	Demoz	Knupp	Chilson	Biggerstaff	Coniglio	Wagner	Clark	Jack Hales
18-Jun	Rauber	Salazar	Parish	Rauber/Jewett		Schumacher	Demoz	Knupp	Chilson	Biggerstaff	Coniglio	Wagner	Clark	Jack Hales
19-Jun	Rauber	Salazar	Parish	Rauber/Jewett		Schumacher	Demoz	Knupp	Chilson	Biggerstaff	Schumacher	Wagner	Clark	Jack Hales
20-Jun	Rauber	Salazar	Parish	Rauber/Jewett		Schumacher	Demoz	Knupp	Chilson	Biggerstaff	Schumacher	Wagner	Clark	Jack Hales
21-Jun	Rauber	Salazar	Parish	Rauber/Jewett		Schumacher	Demoz	Knupp	Chilson	Biggerstaff	Schumacher	Wagner	Clark	David Imy
22-Jun	Rauber	Salazar	Parish	Rauber/Jewett		Schumacher	Demoz	Wilson	Klein	Biggerstaff	Schumacher	Rozoff	Wilson	David Imy
23-Jun	Rauber	Moore	Parish	Rauber/Jewett		Schumacher	Demoz	Roberts	Klein	Biggerstaff	Schumacher	Rozoff	Roberts	David Imy
24-Jun	Rauber	Moore	Parish	Rauber/Jewett		Schumacher	Demoz	Roberts	Klein	Biggerstaff	Schumacher	Rozoff	Roberts	David Imy
25-Jun	Rauber	Moore	Parish	Rauber/Jewett		Parker	Demoz	Roberts	Klein	Biggerstaff	Parker	Rozoff	Roberts	David Imy
26-Jun	Rauber	Moore	Parish	Rauber/Jewett		Parker	Demoz	Roberts	Klein	Biggerstaff	Parker	Rozoff	Roberts	David Imy
27-Jun	Rauber	Moore	Parish	Rauber/Jewett		Parker	Parsons/Haghi	Roberts	Klein	Biggerstaff	Parker	Rozoff	Roberts	David Imy
28-Jun	Rauber	Moore	Parish	Rauber/Jewett	Ferrare/Nehrir	Parker	Parsons/Haghi	Roberts	Klein	Biggerstaff	Parker	Newman	Roberts	David Imy
29-Jun	Ziegler/Rauber	Moore	Parish	Rauber	Ferrare/Nehrir	Parker	Parsons/Haghi	Knupp	Klein	Biggerstaff	Parker	Newman	Weckwerth	David Imy
30-Jun	Ziegler/Rauber	Moore	Geerts	Rauber	Ferrare/Nehrir	Parker	Parsons/Haghi	Knupp	Klein	Biggerstaff	Parker	Newman	Weckwerth	David Imy
1-Jul	Ziegler/Rauber	Moore	Geerts	Rauber	Ferrare/Nehrir	Parker	Parsons/Haghi	Knupp	Klein	Kosiba	Parker	Newman	Weckwerth	Bill Gallus
2-Jul	Ziegler/Rauber	Moore	Geerts	Rauber	Ferrare/Nehrir	Rauber	Parsons/Haghi	Knupp	Klein	Kosiba	Coniglio	Newman	Weckwerth	Bill Gallus

3-Jul	Ziegler/ Rauber	Moore	Geerts	Rauber	Ferrare/ Nehrir	Rauber	Parsons/ Haghi	Wilson	Klein	Kosiba	Coniglio	Newman	Wilson	Bill Gallus
4-Jul	Ziegler/ Geerts	Moore	Geerts	Rauber	Ferrare/ Nehrir	Rauber	Parsons/ Haghi	Wilson	Klein	Kosiba	Coniglio	Newman	Wilson	Bill Gallus
5-Jul	Ziegler/ Geerts	Moore	Geerts	Rauber	Ferrare/ Nehrir	Rauber	Parsons/ Haghi	Wilson	Sikora	Kosiba	Coniglio	Blumberg	Wilson	Bill Gallus
6-Jul	Ziegler/ Geerts	Moore	Geerts	Rauber	Ferrare/ Nehrir	Rauber	Parsons/ Haghi	Hanesiak	Sikora	Kosiba	Coniglio	Blumberg	Turner	Bill Gallus
7-Jul	Ziegler/ Geerts	Moore	Geerts	Rauber	Ferrare/ Nehrir	Rauber	Geerts	Hanesiak	Sikora	Kosiba	Coniglio	Blumberg	Turner	Bill Gallus
8-Jul	Ziegler/ Geerts	Moore	Geerts	Rauber	Ferrare/ Nehrir	Rauber	Geerts	Hanesiak	Sikora	Kosiba	Coniglio	Wagner	Turner	Bill Gallus
9-Jul	Geerts	Moore	Geerts	Rauber	Ferrare/ Nehrir	Ziegler/ Biggerstaff	Geerts	Hanesiak	Sikora	Kosiba	Schumacher	Wagner	Roberts	Bill Gallus
10-Jul	Geerts	Moore	Geerts	Rauber	Ferrare/ Nehrir	Ziegler/ Biggerstaff	Geerts	Hanesiak	Clark	Kosiba	Schumacher	Wagner	Roberts	Bill Gallus
11-Jul	Geerts	Moore	Geerts	Rauber	Ferrare/ Nehrir	Ziegler/ Biggerstaff	Geerts	Hanesiak	Clark	Kosiba	Schumacher	Wagner	Roberts	Bill Gallus
12-Jul	Geerts	Moore	Geerts	Rauber	Ferrare/ Nehrir	Ziegler/ Biggerstaff	Geerts	Hanesiak	Clark	Kosiba	Schumacher	Wagner	Roberts	Bill Gallus
13-Jul	Geerts	Moore	Geerts	Rauber	Ferrare/ Nehrir	Ziegler/ Biggerstaff	Geerts	Hanesiak	Clark	Kosiba	Schumacher	Wagner	Wilson	Bill Gallus
14-Jul	Geerts	Moore	Geerts	Rauber	Ferrare/ Nehrir	Ziegler/ Biggerstaff	Geerts	Hanesiak	Clark	Kosiba	Schumacher	Wagner	Wilson	Bill Gallus
15-Jul	Geerts	Moore	Geerts	Rauber	Ferrare/ Nehrir	Ziegler/ Biggerstaff	Geerts	Hanesiak	Clark	Kosiba	Schumacher	Wagner	Wilson	Bill Gallus

C. Ops Center Staffing Schedules (Geerts)

These are the people filling the various responsibilities in the “situation room” at the Ops center at FHSU during IOPs.

	Alt. Chair	Ops Director	UWKA FS	P-3 flt scientist	DC-8 FS	M radars	MS + MM	MP rep	Lead nowcaster	Asst nowcaster
31-May	Parsons	Salazar	Mueller			Wurman	Parker	Turner	Bill Gallus	student, TBD
1-Jun	Parsons	Salazar	Mueller			Wurman	Parker	Turner	Bill Gallus	student, TBD
2-Jun	Parsons	Salazar	Mueller			Wurman	Parker	Turner	Bill Gallus	student, TBD

3-Jun	Parsons	Salazar	Mueller			Wurman	Parker	Turner	Bill Gallus	student, TBD
4-Jun	Parsons	Salazar	Mueller			Wurman	Parker	Turner	Bill Gallus	student, TBD
5-Jun	Parsons	Salazar	Mueller			Wurman	Parker	Turner	Bill Gallus	student, TBD
6-Jun	Parsons	Salazar	Mueller			Wurman	Parker	Turner	Bill Gallus	student, TBD
7-Jun	Parsons	Salazar	Mueller			Wurman	Parker	Bonin	Bill Gallus	student, TBD
8-Jun	Parsons	Salazar	Mueller			Wurman	Parker	Bonin	Bill Gallus	student, TBD
9-Jun	Parsons	Salazar	Mueller			Wurman	Parker	Bonin	Bill Gallus	student, TBD
10-Jun	Weckwerth	Salazar	Mueller			Wurman	Parker	Feltz	Bill Gallus	student, TBD
11-Jun	Weckwerth	Salazar	Mueller			Wurman	Coniglio	Feltz	Bill Gallus	student, TBD
12-Jun	Weckwerth	Salazar	Mueller			Wurman	Coniglio	Feltz	Bill Gallus	student, TBD
13-Jun	Weckwerth	Salazar	Mueller			Wurman	Coniglio	Feltz	Jack Hales	student, TBD
14-Jun	Weckwerth	Salazar	Mueller	Rauber		Wurman	Coniglio	Feltz	Jack Hales	student, TBD
15-Jun	Weckwerth	Salazar	Mueller	Rauber		Wurman	Coniglio	Feltz	Jack Hales	student, TBD
16-Jun	Weckwerth	Salazar	Pauli	Rauber		Biggerstaff	Coniglio	Feltz	Jack Hales	student, TBD
17-Jun	Weckwerth	Salazar	Pauli	Rauber		Biggerstaff	Coniglio	Smith	Jack Hales	student, TBD
18-Jun	Rauber	Salazar	Pauli	Rauber/Jewett		Biggerstaff	Coniglio	Smith	Jack Hales	student, TBD
19-Jun	Rauber	Salazar	Pauli	Rauber/Jewett		Biggerstaff	Schumacher	Smith	Jack Hales	student, TBD
20-Jun	Rauber	Salazar	Pauli	Rauber/Jewett		Biggerstaff	Schumacher	Smith	Jack Hales	student, TBD
21-Jun	Rauber	Salazar	Pauli	Rauber/Jewett		Biggerstaff	Schumacher	Smith	David Imy	student, TBD
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23-Jun	Rauber	Moore	Pauli	Rauber/Jewett		Biggerstaff	Schumacher	Smith	David Imy	student, TBD
24-Jun	Rauber	Moore	Pauli	Rauber/Jewett		Biggerstaff	Schumacher	Smith	David Imy	student, TBD
25-Jun	Rauber	Moore	Sullivan	Rauber/Jewett		Biggerstaff	Parker	Smith	David Imy	student, TBD
26-Jun	Rauber	Moore	Sullivan	Rauber/Jewett		Biggerstaff	Parker	Smith	David Imy	student, TBD
27-Jun	Rauber	Moore	Sullivan	Rauber/Jewett		Biggerstaff	Parker	Smith	David Imy	student, TBD
28-Jun	Rauber	Moore	Sullivan	Rauber/Jewett	Ferrare/Nehrir	Biggerstaff	Parker	Newman	David Imy	student, TBD

29-Jun	Ziegler/ Rauber	Moore	Sullivan	Rauber	Ferrare/Nehrir	Biggerstaff	Parker	Newman	David Imy	student, TBD
30-Jun	Ziegler/ Rauber	Moore	Sullivan	Rauber	Ferrare/Nehrir	Biggerstaff	Parker	Newman	David Imy	student, TBD
1-Jul	Ziegler/ Rauber	Moore	Sullivan	Rauber	Ferrare/Nehrir	Kosiba	Parker	Newman	Bill Gallus	student, TBD
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3-Jul	Ziegler/ Rauber	Moore	Sullivan	Rauber	Ferrare/Nehrir	Kosiba	Coniglio	Turner	Bill Gallus	student, TBD
4-Jul	Ziegler/ Geerts	Moore	Geerts	Rauber	Ferrare/Nehrir	Kosiba	Coniglio	Turner	Bill Gallus	student, TBD
5-Jul	Ziegler/ Geerts	Moore	Geerts	Rauber	Ferrare/Nehrir	Kosiba	Coniglio	Turner	Bill Gallus	student, TBD
6-Jul	Ziegler/ Geerts	Moore	Geerts	Rauber	Ferrare/Nehrir	Kosiba	Coniglio	Turner	Bill Gallus	student, TBD
7-Jul	Ziegler/ Geerts	Moore	Geerts	Rauber	Ferrare/Nehrir	Kosiba	Coniglio	Turner	Bill Gallus	student, TBD
8-Jul	Ziegler/ Geerts	Moore	Geerts	Rauber	Ferrare/Nehrir	Kosiba	Coniglio	Rozoff	Bill Gallus	student, TBD
9-Jul	Geerts	Moore	Geerts	Rauber	Ferrare/Nehrir	Kosiba	Schumacher	Rozoff	Bill Gallus	student, TBD
10-Jul	Geerts	Moore	Geerts	Rauber	Ferrare/Nehrir	Kosiba	Schumacher	Rozoff	Bill Gallus	student, TBD
11-Jul	Geerts	Moore	Geerts	Rauber	Ferrare/Nehrir	Kosiba	Schumacher	Rozoff	Bill Gallus	student, TBD
12-Jul	Geerts	Moore	Geerts	Rauber	Ferrare/Nehrir	Kosiba	Schumacher	Rozoff	Bill Gallus	student, TBD
13-Jul	Geerts	Moore	Geerts	Rauber	Ferrare/Nehrir	Kosiba	Schumacher	Rozoff	Bill Gallus	student, TBD
14-Jul	Geerts	Moore	Geerts	Rauber	Ferrare/Nehrir	Kosiba	Schumacher	Rozoff	Bill Gallus	student, TBD
15-Jul	Geerts	Moore	Geerts	Rauber	Ferrare/Nehrir	Kosiba	Schumacher	Rozoff	Bill Gallus	student, TBD

D. Student Participation (Kosiba)

E. Contact Information (Salazar)

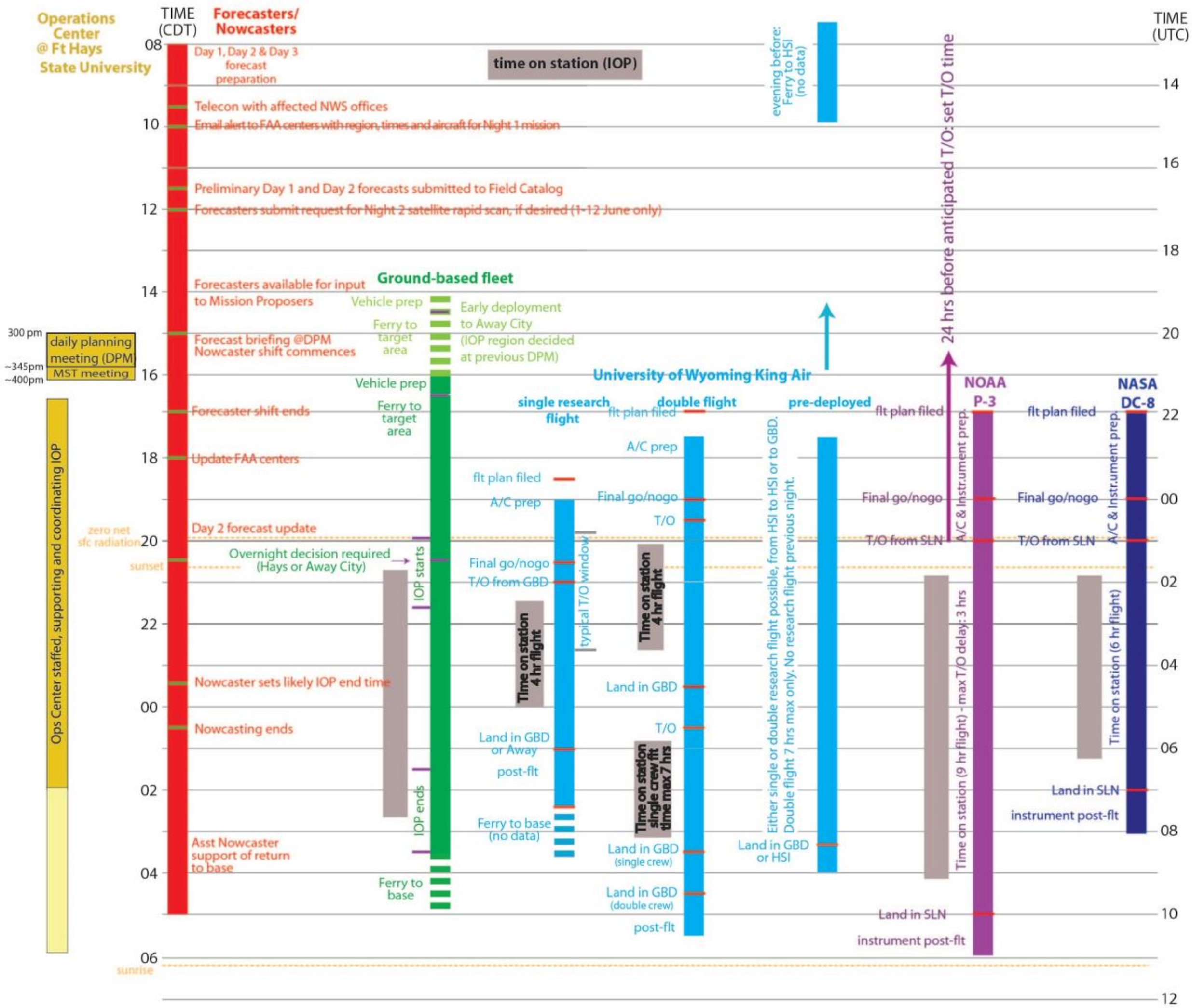
F. Housing Information (Wurman)

G. PECAN Operations Calendar (Salazar)

- The PECAN field phase is 1 June - 15 July, with the first possible IOP starting late on 1 June (2 June in UTC time) and the last possible IOP ending before dawn on 16 July (2 July in UTC time).
- The first forecast discussion is on Friday 29 May (look for a readytalk announcement)
- [tentative plan] Sat 30 May: Open House / PR day: Hays airport (KHYS), 1-4 pm, Sat 30 May

- [tentative plan] Sat 30 May: daily forecast discussion delayed to 6 pm, FHSU campus + Readytalk
- [tentative plan] Sat 30 May: all-hands meeting: FHSU campus, 7-9 pm
    - Project introduction, daily schedule, updates and decision making process, a walk through the first IOP (what should happen)
    - Overview of ground facilities including safety and security
    - Project communications protocols and procedures
    - Project key points of contact, emergency agency information
    - Ft Hays State U. site safety and security protocols (a university representative will be invited for this)
    - Operations center access and security
    - The night time schedule, (what to do and not to do in handling the required change to your circadian clock)
    - Other general logistics matters, etc. etc.

H. Daily Schedule Diagrams (Weckwerth)


Operations Center @ Ft Hays State University
TIME (CDT)
Forecasters/ Nowcasters
Day 1, Day 2 & Day 3 forecast preparation
time on station (IOP)
Telecon with affected NWS offices
Email alert to FAA centers with region, times and aircraft for Night 1 mission
Preliminary Day 1 and Day 2 forecasts submitted to Field Catalog
Forecasters submit request for Night 2 satellite rapid scan, if desired (1-12 June only)
Forecasters available for input to Mission Proposers
Ground-based fleet
Vehicle prep
Early deployment to Away City (IOP region decided at previous DPM)
Ferry to target area
300 pm
daily planning meeting (DPM)
~345pm
MST meeting
~400pm
Forecast briefing @DPM
Nowcaster shift commences
University of Wyoming King Air
Forecaster shift ends
Update FAA centers
Day 2 forecast update
zero net sfc radiation
sunset
Overnight decision required (Hays or Away City)
IOP starts
IOP ends
Nowcaster sets likely IOP end time
Nowcasting ends
Asst Nowcaster support of return to base
Ferry to base
Ops Center staffed, supporting and coordinating IOP
single research flight
double flight
pre-deployed
evening before: Ferry to HSI (no data)
flt plan filed
A/C prep
Final go/nogo
T/O from GBD
typical T/O window
Time on station 4 hr flight
Land in GBD or Away
post-flt
Ferry to base (no data)
T/O
Land in GBD
Time on station single crew flt time max 7 hrs
Land in GBD (single crew)
Land in GBD (double crew)
Either single or double research flight possible, from HSI to HSI or to GBD. Double flight 7 hrs max only. No research flight previous night.
Land in GBD or HSI
24 hrs before anticipated T/O: set T/O time
NOAA P-3
A/C & Instrument prep.
T/O from SLN
Time on station (9 hr flight) - max T/O delay: 3 hrs
Land in SLN
instrument post-flt
NASA DC-8
Time on station (6 hr flight)
TIME (UTC)
sunrise

I. Aircraft Payloads and Cabin Layouts (Salazar)

Table I-1. NASA DC-8 science instrumentation payload. Standard meteorological and navigational suite is provided by DC-8

Instrument	PI	Species/Parameter	Method
LASE	Ferrare	H2O Vapor and aerosol profile	Lidar
NAST-I	Larar	Temperature and relative humidity profile	FTS

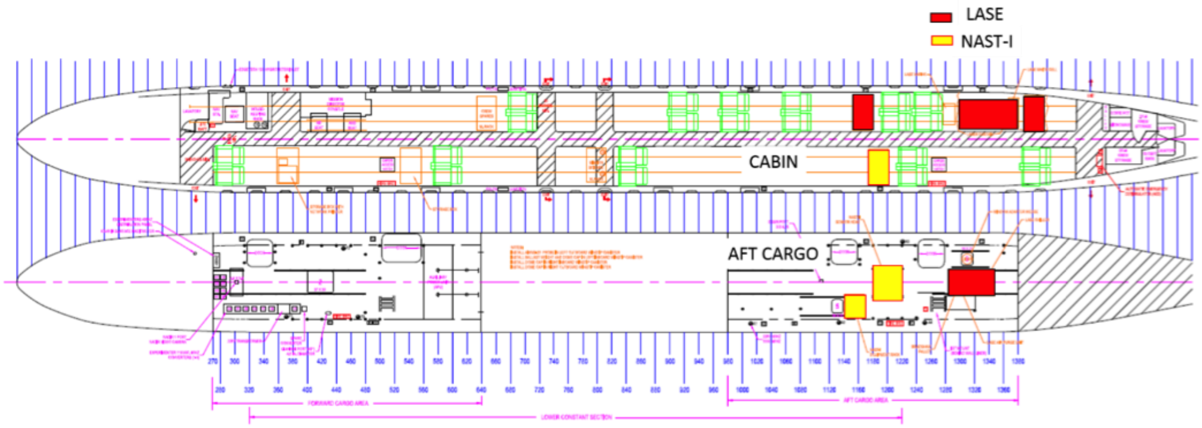


Figure I-1. Layout of DC-8 payload. Top half and bottom half of the figure represents instrument (red-LASE, yellow-NAST-I) components that reside in the main cabin and aft cargo pit, respectively.

J. Flight Pattern Segment Diagrams (Geerts)

K. ReadyTalk Connection Information (Salazar)

L. Maps (Salazar)

M. McConnell AFB Rules and Regulations (Salazar)

N. Salina Airport Rules and Regulations (French)

Full document can be found at:
www.salinaairport.com/pdfs/FINAL%20-%20SLN%20Rules%20and%20Regs.pdf

1. GENERAL RULES AND REGULATIONS.

1.1 Abandoned, Derelict or Lost Property. Property including, without limitation, Aircraft, vehicles, equipment, machinery, baggage, or personal property shall not be abandoned on the Airport. Abandoned, derelict, or lost property found in public areas at the Airport shall be reported to the executive director. Property unclaimed by its proper owner or items for which ownership cannot be established will be handled in accordance with applicable law. Nothing in this section shall be construed to deny the right of operators and other lessees to maintain "lost and found" service for property of their customers and/or employees.

1.2 Accidents or Incidents. In addition to other appropriate notifications and actions, accidents resulting in damage to property, injury requiring medical treatment, or interference with normal Airport operations shall be promptly reported to the executive director, in addition to other appropriate notifications.

1.3 Airport Liability. The Airport Authority and the City of Salina, Kansas, and their agents or employees shall not be liable for loss, damage or injury to persons or property arising out of any accident, incident or mishap of any nature whatsoever and/or from any cause whatsoever and/or from any cause whatsoever to any individual, aircraft, or property occurring on the Airport, or in the use of any of the Airport Authority facilities.

1.4 Airport Operations. The executive director, or his designee, may delay, restrict, or prohibit, in whole or in part, any operations at the Airport for any justifiable reason.

1.5 Animals. Domestic pets and animals, except animals required for assistance or law enforcement dogs, are not permitted on the AOA of the Airport or in the Airport passenger terminal building, unless being transferred or shipped, and then only if controlled and restrained by a leash, harness, restraining strap, portable kennel, or other appropriate shipping container. Leashes, harnesses and straps shall not exceed six (6) feet. It shall be the responsibility of the owner or handler to exercise control over the animal at all times. Owners or handlers are responsible for the immediate removal and disposal of animal waste. No person, except those authorized in writing by the executive director shall intentionally hunt, pursue, trap, catch, injure, or kill any bird or animal on the Airport. Feeding or otherwise encouraging the congregation of birds or animals on the Airport is prohibited.

1.6 Buildings and Remodeling. It shall be unlawful for any person, other than the Authority, to construct, reconstruct or remodel any building or other improvement on the Airport without first obtaining written permission from the Authority and applicable permits from the City of Salina. Any changes, alterations, or repairs made without proper approval, and any damage resulting therefrom shall be paid for by the person responsible and in accordance with the direction of the Authority.

1.7 Commercial Activities. Commercial activity of any kind on the Airport requires the express written permission of the Authority through a specifically authorized lease, sublease, license, permit or written temporary permission, and upon such terms and conditions as they may prescribe, and the payment of any required fees. Unless otherwise provided in such document, any permission may not be assigned or transferred and shall be limited solely to the approved activity.

1.8 Compliance with Regulatory Measures. All persons occupying or using, engaging in an aeronautical activity on, or developing Airport land or improvements shall comply, at the person's or entity's sole expense, with all applicable regulatory measures including, without limitation, the Salina Municipal Airport Minimum Standards, these Rules, and those of the federal, state, and local government and any other agency having jurisdiction over the Airport.

1.9 Damage to Airport Property. Any and all Airport property, real or personal, and/or facilities destroyed, broken, or damaged by accident or otherwise shall be paid for by the person responsible for the damage. Aircraft equipped with tail or landing skids or other devices, which will damage pavement or sod areas shall not be operated on the Airport.

1.10 Fire/Open Flames. Open flames of any kind are prohibited except (a) as provided in a burn permit; or (b) for open flames utilized by operators/lessees in the performance of approved aircraft maintenance. Burn permits may be issued in the discretion of the Salina Fire Department and only in compliance with applicable building and/or fire codes. Smoking and the use of any open-flame device is prohibited on any apron, or within fifty (50) feet of any aircraft, fuel truck, fueling facility, or other flammable storage facility. Any fires (regardless of the size of the fire or whether or not the fire has been extinguished) shall be reported immediately to 911. No welding/cutting activities shall be conducted on the Airport without an approved fire extinguisher and a person trained in its proper usage present for the duration of any welding/cutting activities.

1.11 Firearms. No persons, except law enforcement officers on official duty, authorized federal agents on official duty, airport employees authorized by the executive director for wildlife hazard reduction purposes, members of the Armed Forced of the United States on official duty, and authorized foreign armed forces on official duty, shall carry any firearms or any explosives on Airport property. Unloaded and properly secured firearms may be stored as cargo for travel on Airport property.

1.12 General Conduct. No person shall use or otherwise conduct himself upon any portion of the Airport in any manner contrary to any posted or otherwise visually indicated directions applicable to that area. Overnight camping or lodging on the Airport is prohibited. Except for the Airport fire station, use of any facility on, or area of, the Airport for sleeping or other purposes in lieu of a hotel, motel, residence or other public accommodation is prohibited. No person shall use, keep, or permit to be used or kept, any foul or noxious gas or substance at the Airport, or permit the Airport to be occupied or used in a manner offensive or objectionable to other users for any reason. Spitting on, marking, or defacing the floors, walls, or other surface of the Airport is prohibited.

1.13 Hazardous Materials. No person shall cause or permit any hazardous material to be used, generated, manufactured, produced, stored, brought upon, or released, on, under or about any premises, or transported to and from the Airport, by itself, its agents, employees, contractors, invitees, sublessees or any third party in violation of any environmental law, provided that, in no circumstances shall any person or entity cause or permit any extremely hazardous substance or toxic chemical to be used, generated, manufactured, produced, stored, brought upon, or released, on, under or about the Airport, or transported to and from any premises. All persons or entities shall promptly notify the Airport of any action or condition that is contrary to any prohibition in the previous sentence. Approved hazardous material must be stored in suitable containers that are properly secured. Material Safety Data Sheets (MSDS) for all hazardous materials shall be maintained on site so as to be readily available to emergency responders in the event of an emergency and for review by the Salina Fire Department. No fuels, oils, dopes, paints, solvents, acids, or any other hazardous material shall be released in storm water conveyances, drains, catch basins, ditches, the AOA or elsewhere on the Airport. Tenants and operators who generate and dispose of "Special Waste" shall comply with the requirements of 40 CFR Sections 266 & 273. Special waste includes widely generated wastes such as batteries, agricultural pesticides, mercury containing devices, hazardous mercury-containing lamps, and used oil. Used engine oil shall be disposed of only at approved waste oil stations or disposal points. Secondary containment is required for the storage of gasoline, oils, solvents, or other hazardous waste in drums or receptacles. Aviation fuels or automotive gasoline in quantities greater than five (5) gallons shall not be stored at the Airport without the prior written permission of the executive director. Any fuels must be stored in accordance with any applicable codes, regulations, and requirements for the storage of volatile fuels. No hazardous substance or pollutant shall be disposed of on the Airport or into the air at the Airport during aircraft preflight inspection.

1.14 Hazardous Material Spills. Any person who experiences overflowing or spilling of oil, grease, fuel, alcohol, glycol or any other hazardous material anywhere on the Airport shall immediately call 911. Persons involved in hazardous material incidents shall take action to prevent/minimize danger to personnel, property and the environment while awaiting arrival of the Salina Fire Department personnel.

At the discretion of the Salina Fire Department, the entity responsible for the spill may be required to clean and properly dispose of the material/substance which shall be performed in compliance with all applicable federal, state, and local regulations and guidelines. In addition, the entity may be required to provide the Salina Fire Department with required documentation of proper disposal. Any costs incurred by the Authority or Salina Fire Department in such instances shall be reimbursable to the Authority and/or the Salina Fire Department by the person responsible for the spill.

1.15 Licenses, Permits, Certifications and Ratings. Operators shall obtain and comply with all necessary licenses, permits, certifications, or ratings required for the conduct of operator's activities at the Airport as required by the executive director or any other duly authorized agency prior to engaging in any activity at the Airport. Upon request, operators shall provide copies of such licenses, permits, certifications, or ratings to the Airport within 5 business days. Operators shall keep in effect and post in a prominent place all necessary or required licenses, permits, certifications, or ratings. 28 April 2012.

3.16 Painting. Doping processes, painting, or paint stripping shall be performed only in those facilities approved for such activities by the executive director and in compliance with air quality regulations, the Fire Code, and the Authority's Storm Water Pollution Prevention Plan (SWPPP), and 14 CFR Part 43.

3.17 Preservation of Property. No person shall destroy or cause to be destroyed, injure damage, deface, or disturb, in any way, property of any nature located on the Airport. Any person causing or responsible for such injury, destruction, damage or disturbance to Airport-owned property shall report such damage to the executive director and shall reimburse the Airport the full amount of repair and replacement of property. No Person shall take or use any aircraft, air-craft parts, instruments, tools owned, controlled, or operated by any person while on the Airport or within its hangars, except with the consent of the owner or operator thereof. No person shall prevent the lawful use and enjoyment of the Airport by others. Any activity which results in littering, environmental pollution or vandalism on the Airport is not permitted and violators are subject to arrest.

3.18 Signage/Advertisements. Written advertisements, signs, notices, circulars, and/or hand-bills may be posted or distributed only with the prior written permission of the executive director. The Airport has the right to remove any such sign, placard, picture, advertisement, name or no-tice in any such manner as the Airport may designate. No signage may be installed on the Airport without the prior written approval of the executive director.

3.19 Solicitation, Picketing, and/or Demonstrations. Airport users shall comply with any Airport policy regarding solicitation, demonstration, or the distribution of literature on the Airport.

3.20 Sound Amplifying Devices. Sound amplifying devices such as megaphones, public address systems, or any other device designed to amplify and broadcast the human voice over a distance are prohibited on the Airport unless written approval from the Executive Director is given prior to their installation and use.

3.21 Special Events. Special events on the Airport require written coordination, regulation and authorization of the executive director prior to the public disclosure or advertisement of the event. Certain events may require an executed lease, operating agreement or permit with the executive director.

3.22 Through-the-Fence Activities. All "Through-the-Fence" activities may be conducted only in accordance with written agreement with the City. No such "Through the Fence" activity shall be authorized except in strict accordance with the Authority's Minimum Standards.

3.23 Trash and Other Waste Containers. No person shall dispose of garbage, paper, refuse or other materials on the Airport except in receptacles provided for that purpose. The executive director shall designate areas to be used for garbage receptacles and no other areas shall be utilized. Tenants, operators and other users of the Airport shall not move or otherwise relocate Airport-placed trash and waste containers. Garbage, empty boxes, crates, rubbish, trash, papers, refuse, or litter of any kind shall not be placed, discharged, or deposited on the Airport, except in the receptacles provided specifically for that purpose. The burning of garbage, empty boxes, crates, rubbish, trash, papers, refuse, or litter of any kind on the Airport is prohibited. Trash and other waste containers at the Airport shall only be used for trash generated on Airport property. Trash and other waste container areas shall be kept clean and sanitary at all times. Tenants and operators shall ensure that their trash and waste containers are emptied with sufficient frequency to prevent overflowing, shall be cleaned with sufficient frequency to prevent the development of offensive odors, and are equipped with securely fastened lids which shall be closed and fastened at all times other than while the receptacles are being loaded or unloaded.

3.24 Use of Roadways and Walkways. No person shall travel on the Airport other than on the roadways, walkways, or other areas provided for the particular class of traffic, or occupy roadways or walkways in such a manner as to hinder or obstruct their proper use. No person shall operate any type of vehicle on the roads or walks except as designated by the executive director.

3.25 Wildlife Hazard Reduction. The executive director, and his designee, are authorized to use FAA approved wildlife hazard reduction techniques including, but not limited to, discharge of firearms on Airport property. Use of lethal reduction techniques will comply with FAA guidelines, Kansas Department of Wildlife and Parks and Federal permit and tag requirements, and will be accomplished by personnel who are trained in the use of firearms and who have an excellent knowledge of wildlife identification. The proper gun and ammunition will be used for the situation. The location in which wildlife reduction techniques will be used should be examined for safety purposes. Firearms should be discharged in a safe manner away from people and property to avoid injury.

4. Security and Safety.

Scheduled air carrier and public charter air carrier aircraft operators using the Airport are subject to the Airport Security Program, as may be amended from time to time. Persons in violation of TSA, FAA and/or Airport security rules, including those set forth herein and elsewhere, may be denied access to the Airport, may have access or driving privileges revoked, and/or may be fined or otherwise penalized in accordance with applicable regulatory measures. Operators who are required to provide controlled access to their facilities and/or aircraft for security reasons are responsible for ensuring that all personnel are trained on the appropriate procedures for authorizing non-employees and passengers access to their respective facilities and/or aircraft.

4.1 Restricted or Secure Areas. Restricted or secure areas on the Airport are those areas that are identified in the ASP as areas where no person is allowed access unless issued Airport identification that is recognized in the ASP.

4.1.1 No person shall enter any restricted or secure area except those persons directly engaging in work or an aviation activity that must be accomplished therein; and

4.1.1.1 Having prior authorization of the Authority or under appropriate supervision or escort; or

4.1.1.2 Employed by or representing the FAA, TSA, DHS, or recognized in the ASP as being authorized to access to certain secured areas of the Airport.

4.1.2 No person shall cause any object to be located within eight (8) feet of the Airport perimeter fence, which may assist an unauthorized individual in accessing a secure area.

4.1.3 Any gate or fence condition that would allow unauthorized access to restricted or secure areas of the Airport must be reported immediately to the executive director. Any attempts by any persons to gain unauthorized access to any such area, and any conditions that would adversely affect the safety or

security of aircraft operations shall be reported immediately to the Salina Police Department and the executive director.
4.1.4 Any person who violates security related regulatory measures may be denied future entry into a restricted or secure area.
4.1.5 All persons shall wear and visibly display their approved Airport identification recognized in the ASP on their outermost garment, waist or higher, while inside a secure area.
4.1.6 Airport identification holders must notify the executive director of any entry or attempted entry to a secure area by any unauthorized person, or by any unauthorized means.
4.1.7 Any person with proper Airport identification as required by the ASP may bring a person without proper Airport identification into a secure area if the person has a valid reason for being inside the secure area and if the person is provided continuous escort by a person with proper Airport identification. A continuous escort requires that the escorted person remains in close proximity to the Airport identification holder at all times while inside the secure area. The Airport identification holder shall bear full responsibility for the actions of the person being escorted.
4.2 Sterile Area. Any persons desiring to enter a sterile area are subject to security screening.
4.3 Security Access.
4.3.1 Security gates (pedestrian or vehicular) that provide access to the AOA shall be kept closed and locked at all times, except when actually in use. All access gates to the AOA through a tenant's leased premises are Operator's/lessee's responsibility and shall be monitored and secured in a manner that will prevent unauthorized access.
4.3.2 Vehicle operators shall stop their vehicle and allow the gate to fully close before proceeding, and shall also ensure that no other vehicles or persons gain access to the Airport while the gate is in the process of closing or not fully closed. If the vehicle operator cannot prevent such access, the vehicle operator shall immediately notify the executive director and the Salina Police Department.
4.3.3 Tampering with, interfering with, or disabling the lock, or closing mechanism or breaching any other securing device at the Airport is prohibited.
4.3.4 Persons who have been provided either a code or a device for the purpose of obtaining access to the AOA shall not divulge, duplicate, release, or otherwise distribute the same to any other person.
4.3.5 Persons with authorized access to the AOA may escort an unauthorized vehicle directly to and from the immediate area around the aircraft hangar for the purpose of loading and unloading.

O. Safety Plan for Lidar Operations (Ferrare)

<u>Non-Ionizing Radiation Safety Plan</u>

for

<u>LASE Airborne Lidar Operations for Atmospheric Science Field Studies</u>

1. EXPERIMENT BACKGROUND

LASE is one of many active and passive instruments participating in the <u>P</u>lains <u>E</u>levated <u>C</u>onvection <u>A</u>t <u>N</u>ight (PECAN) Program. This system, in the present configuration and method of operation, successfully participated in the AFWEX (November 15-December 15, 2000), SOLVE (Dec. 99-March 00) PEM-Tropics B (Dec. 98-March 99) and the CAMEX-3 Program (July-September 1998), CAMEX-4 (July-September 2001), IHOP (May-June 2002), NAMMA (August- September 2006), and GRIP (July-September 2010) onboard the NASA DC-8 (NA817).

The objective for LASE during the PECAN Program is to measure the distribution of water vapor and aerosols associated with pre-convective environment of nocturnal mesoscale convective systems (MCSs) with the primary object to improve the capability of understanding of mechanisms that initiate, organize and maintain this nocturnal warm-season precipitation. LASE will also provide real time measurements of nadir and zenith water vapor and aerosols from the NASA DC-8 aircraft, to assist investigators in the planning, execution, and assessment of PECAN flight missions. The base of operations for the DC-8 aircraft will be at Salina Kansas.

2. AREA OF OPERATIONS

The LASE system will be shipped to Palmdale, CA for integration and test flights on the NASA DC-8 during May 2015. After 2-3 test flights from Palmdale, the DC-8 will then deploy for flights over the Central US regions. It is anticipated that about 8 flights will be conducted from the base of operations during the June 1 to July 15, 2015 time period.

All ground and flight operations of the LASE instrument will only be conducted in the DC-8 aircraft.

3. PROPOSED SCHEDULE

The PECAN deployment plan has a schedule of instrument integration and flight-testing aboard the DC-8 beginning May 15, 2015 and science flights will be conducted during June 1 to July 15, 2015 over the Central US. Then the DC-8 will return to Palmdale on July 16, 2015, to remove the instruments, which will complete the mission.

4. LIDAR PERSONNEL

The following Personnel are NASA LaRC laser certified workers who will be working with the LASE system at AFRC, and onboard the DC-8 NASA 817.

Laser Certified Personnel

Amin Nehrir	Research Scientist	NASA LaRC
Johnathan Hair	Research Scientist	NASA LaRC

Richard Ferrare	Research Scientist	NASA LaRC
Anthony Notari	Research Scientist	NASA LaRC
Syed Ismail	Research Scientist	NASA LaRC
Carolyn Butler	Lead Data Acquisitions Specialist	Contractor
James Collins	Research Engineer	Contractor
Susan Kooi	Data Acquisition Specialist	Contractor

5. DESIGNATED SAFETY OFFICER(S)

Amin Nehrir (Phone: 757-864-6107), Johnathan Hair (Phone: 757-864-1406), and Richard Ferrare (Phone: 757-864-9443) will be the designated Laser Safety Officer; as such, they will be responsible for maintaining the overall safe operations for the LASE instrument. In their absence or at their designation, Anthony Notari, Carolyn Butler, Susan Kooi, or James Collins will assume this responsibility.

6. SYSTEM DESCRIPTION

During the PECAN field deployment, the LASE instrument will be configured to measure tropospheric water vapor and aerosols in the nadir and zenith when flying on the DC-8.

The Tunable Laser System (TLS) of the LASE Instrument contains three lasers: (1) a Nd:YAG (Class IV) pump laser operating at 1064-nanometers and 532-nanometers, (2) a Ti:sapphire (Class IV) power oscillator operating at selected wavelengths in the 813-818-nanometers region, and (3) a GaAIAs (Class III) laser diode operating at selected wavelengths in the 813-818-nanometer region. All three lasers are contained within an opaque fiberglass housing identified as the Laser Thermal Enclosure (LTE). Energy coming out of the housing is limited to that of the Ti:sapphire and the laser diode. The Ti:sapphire has been designed to transmit maximum of 100-millijoules of energy (split into both the nadir and zenith directions) into the atmosphere for measurement of water vapor. The current measured energies are 80mJ in the nadir and 10mJ in the zenith. The laser diode has only microwatts of power exiting the DC-8 and entering the atmosphere and the Nd:YAG laser is not transmitting any light; therefore, for eye safety considerations, only the Ti:sapphire is of any concern outside of the aircraft. The energy of the Ti:sapphire laser beam which exits the DC-8 may also be changed so that the MPE requirements are met for changes in altitude during a flight. The calculated divergence laser energy includes the following systematic error sources, uncertainties, mission considerations, and performance criteria: (1) DC-8 altimeter error; (2) divergence tolerance; and (3) maximum altitude of topographical features falling within the planned flight path.

The double-pulsed Ti:Sapphire laser, which serves as the transmitter for the LASE Differential Absorption Lidar (DIAL) instrument, will be transmitting into the atmosphere approximately 100-millijoules of energy at selected wavelengths within the spectral region of 813-818 nanometers. The pulse width is 35 nsec and the system emits double pulses at 5Hz. The beam, at emission from the LTE, has a width of 5 mm and a divergence of 1.3 mrad (1/e2). The double pulses are separated by 400 μsec and result in an overlapping beam footprint. The laser pulse energy is split with 80 mJ being directed to the nadir and 10 mJ directed to the zenith. The laser safety calculations are done for a multiple-pulse system running at 10 Hz with a maximum exposure time of 0.25 sec. The separation of the pulses is longer than t_{min}, which means that the pulses can be considered spate rather than summing the energy.

The LASE system configuration is shown in Figure O-1.

7. NOHD Calculations

The MPE for an 815 nm beam with a 35 ns pulse width is 3.4 e-7 J/cm2, with the single pulse MPE being the most restrictive.

For the nadir beam with a single pulse energy of typically 80 mJ per pulse the NOHD is 19,540 ft.

For the zenith beam with a single pulse energy of typically 10 mJ per pulse the NOHD is 6,910ft.

The nominal planned operating altitude of the DC-8 is 10 km (32,000 feet) which is over 30,000 feet mean AGL over Kansas and Oklahoma. Actual laser output power will be adjusted according to the radar altitude to ensure that the beam is below the MPE on the ground. While flying at lower altitudes the energy being reduced from the nadir beam may be directed to the zenith beam.

Although the probability of the beam illuminating another aircraft operating at a lower altitude is very remote, it is important to monitor the operational airspace for the presence of other aircraft and take actions to prevent any accidental illumination. The DC-8 is equipped with a TCAS radar system as well as a downward looking digital camera to monitor the surrounding airspace. The beam will also be terminated during banking maneuvers in excess of 10 degrees (20 degrees over water).

As this is an infrared system the reduced FAA exposure limits for visual interference do not apply.

8. OPERATIONAL PROCEDURES

LASER PRECAUTIONS FOR OPERATION ON NASA DC-8

The specific details of the in-flight eye safety procedures will be worked out between the DC-8 mission manager and the DIAL PI/Co-PI. In general, the mission manager will provide a 3-

minute warning to the PI prior to any decrease in aircraft altitude. Laser transmission will be limited to banks angles of less than 10 degrees over land (20 degrees over water). The radar and GPS altitude will be monitored on the LASE data acquisition system rack in addition to the DC-8 mission manager's console. Laser transmission will be terminated if other aircraft are observed to pass within flight path and will remain off until permission to resume operations is granted from the mission manager. The mission manager will have the final say relative to any laser safety matters on the flights. A metal shutter on the aircraft will be located over the LASE output hatch window anytime the laser is non-operational. When the instrument/laser is ready to fire, the shutter over the hatch window will be opened. When laser operations have finished, the shutter will be closed. Furthermore, an internal laser shutter inside of the LTE allows for rapid shuttering of the transmitted beam during flight to prevent illumination of targets directly above or below the DC-8, or during high bank angles. Detailed procedure for in flight and ground testing of the LASE lidar are as follows:

1. During all flights of the LASE lidar instrument onboard the NASA DC-8, operation of the lidar instrument will be controlled by the NASA DC-8 mission manager or his designee. The Mission Manager will maintain direct contact with the Pilot in Charge during flight operations and the Mission Manager will have the final decision on any laser transmission during flight and ground testing.

2. Direct communication between the laser operator and the Mission Manager will be requested for clearance to transmit the laser beams during flights and ground testing. This ensures that all personnel and the FAA have been notified of operations and the communication protocols have been established and that all safety control measures are satisfied.

3. Communication with the Mission Manager will be maintained via use of the headsets for all operations when there is laser transmission outside the laser controlled area described above. This includes ground atmospheric testing and flight operations.

4. During airborne operations, a dedicated observer will scan the region around the aircraft to identify any encroaching aircraft. The observer will also have a video feed of the camera displays to monitor the area for any nonparticipating aircraft. The observer will notify the Mission Manager to terminate any laser operation before aircraft approach the laser beam paths (nadir and zenith directions).

5. TCAS is also used as an additional control measure to ensure approaching aircraft are detected. Monitoring of the TCAS is possible via the onboard data system and the PIC and Mission Manager.

6. Communication with air traffic control will be maintained to provide additional coordination and detection of approaching aircraft and laser transmission will be terminated immediately upon request.

7. The aircraft shutters over the exit and receive windows are controlled by the mission manager and the crew and are open only after a Crew Member has given the all clear during flight to the Mission Manager. The aircraft shutters are closed before the call for seat belts and landing. The laser shall not transmit from the aircraft during take-off and landing.

8. Laser transmission will only be started after clearance from the Mission Manager and Pilot in Charge (PIC) has been granted.

9. The Laser Safety Officer (LSO) shall have the capability to remotely attenuate or block the transmitted beams from the Data Acquisition System (DAS) rack. Moreover, the LSO shall have the capability to shut down the lasers with manual switches located on the lasers and the DAS rack. The mission manager also shall have the capability to terminate power to the DIAL system for final redundancy.

10. The laser divergences are set before each mission and measured to ensure values are correct and consistent with the stated values in the NOHD calculations above.

11. At regular intervals (~1-2 sec) the transmitted beam energies shall be monitored to ensure that they are less than the stated maximum values. All energies are measured before flight and before initiating transmission outside the aircraft.

12. During flight, an update of the altitude, pitch, and roll angles are recorded and will be monitored in addition to redundant monitoring by Mission Manager's console.

13. Beams are mechanically steered and are limited in small angles (<3 degrees) due to the beam shields installed on the system.

14. All laser transmission shall be blocked during bank angles of >10 degrees when flying over land and >20 degrees when flying over open water.

15. Laser transmission will be limited by NOHD and altitude AGL (above ground level) and based on wavelengths to ensure that all beams are not hazardous at ground levels.

16. For the LASE IR beams, the nadir beams will be blocked when flight level is < 20 kft AGL. Note that this is less than the NOHD altitude and therefore is a conservative altitude limit.

17. Zenith beams will remain on during all flight altitudes except during take-off and landing.

18. Because the LASE IR beam is beyond the visible range, night time lasing restrictions in Critical Flight Zone and the Laser Free Flight Zones do not apply.

LASER PRECAUTIONS CHECKLIST FOR GROUND OPERATIONS

1. At times when the laser beam is to be tested through the DC-8 nadir hatch window, the laser beam will be terminated on the hanger floor using an energy meter. Black plastic/cloth will be placed around the LASE hatch window and shall extend from the DC-8 to the hanger floor. This will ensure that no scattered Ti: Sapphire laser energy enters the general hanger area. The area around the telescope/laser hatch window will also be roped off to ensure that personnel located at the DC-8 are kept clear of the testing area. The laser energy will be reduced as much as possible to perform these alignments. The Ti:Sapphire laser beam exiting the plane will be fully contained in the DC-8 during flights so the black curtain will be removed.

2. Display *"DANGER - LASER RADIATION/V'* sign at the entrance of the DC-8 when the laser will be firing.

3. During ground testing, any side windows on the DC-8 exposed to scattered Ti:Sapphire laser energy will be covered. During DC-8 flights this covering may be removed since the Ti:Sapphire laser beam is fully contained and no scattered energy is present.

4. During ground operation of the LASE laser, a rotating and flashing red light will be located near the LASE instrument to alert personnel that the laser is firing. The light will only be "ON" when the laser is firing.

5. While the laser is operating, all personnel in the LASE instrument area (exposed to open laser beams) in the DC-8 will wear appropriate laser safety eye wear when necessary. Eyewear specs are listed in the data table at the end of the procedure.

6. All laser work accomplished in the DC-8 will be done while the laser beam is at waist height or below, not eye level.

7. During ground atmospheric testing, the mission manager will coordinate with any local airports before transmitting the beam outside of the aircraft.

8. Ensure that beam dumps are in place.
9. Perform laser precautions checklist and signoffs.

10. Perform all laser tests according to approved procedures and signoffs.

11. Alert the DC-8 Crew Chief of all laser operations.

12. During ground atmospheric testing coordination with the local FAA center will be done in advance and as required by the FAA letter of non-objection.

13. During ground atmospheric testing an observer on the ground will be used to monitor the area for overhead aircraft and give the signal to terminate laser emission to the mission manager if aircraft approach the beam path. The observer is required to be in direct contact with the

mission manager or LSO to terminate laser transmission during ground tests. A laser control switch is used to block laser beam transmission by the designated safety officers in direct communications with the ground observer.

9. Emergency Procedures

In the event of a suspected laser eye exposure, the LASE team leader will immediately notify the mission manager. Professional medical assistance should be sought as soon as possible. If a laser eye injury is determined to have occurred then notify the LaRC Laser Safety Officer at 757-342-2843. If knowledgeable medical help is not immediately available go to the nearest emergency medical facility and consult with the DoD 24hr Laser Injury Hotline at 1-800-473-3549, they can provide treatment and diagnosis advice to the doctors.

Energy versus NOHD table

Pulse energy in mJ	NOHD in meters	NOHD in feet
90	6316	20,720
80	5956	19,540
70	5571	18,280
60	5161	16,930
50	4710	15,450
40	4211	13,820
30	3650	11,980
20	2978	9,770
10	2105	6,910

10. Figure 1 - Installation aboard DC-8

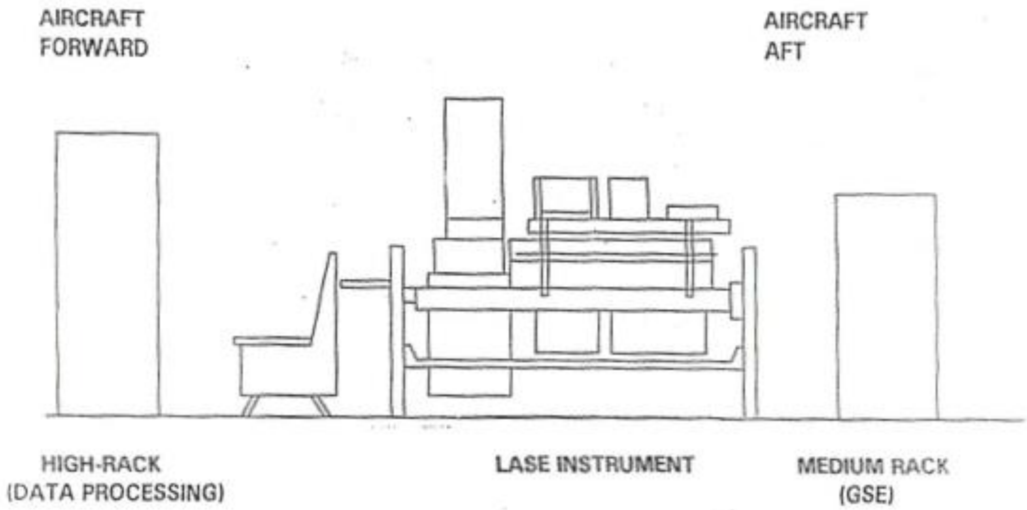


Figure 1. LASE Instrument Mounting Configuration In The DC-8

LASER TABLE (based on ANSI Z136.1-2000) **NIR Permit #**
Calculation by EasyHaz LSO2014 v1.01

Laser identification	Laser specifications	Direct eye exposure	Diffuse eye exposure	Skin exposure			
ID #	Type	Make & Model	Com-ments	Class	Wave-length	Mode	Bea Siz
					(nm)		(mn
1	Nd:YAG		(1)	4	1064	Pulsed	7.5
			(1)		532	Pulsed	7.5
2	Ti: Sapphire		(1)	4	815	Pulsed	5
Misc	HeNe, diode	Various	Several	2-3b	400-700	CW	~1

(1) System operates at 5 Hz w/ doubled pulse. Analysis done using a 10Hz rep rate and separating the pulse energies.

NOTE: This data table is relevant for laser operations within the aircraft or for ground operations where the exposure time is longer.

P. Lidars and eye safety (Geerts)

Table 1: PECAN Lidar Specs

name	platform	PI	Operating Group	Lidar Type	Eye-safe class	Wavelength	Eye-s distar
Mobile PISA							
Wind Tracer Lidar	free	Howie Bluestein / Paul Buczynski	NPS	Doppler	1M	2000 nm	Safe to r eye; Hazardo with opti instrume
CLAMPS HALO	MP1	Dave Turner, Tim Bonin	OU	Halo Streamline	1M	1500 nm	0 m
MIPS HALO	MP2	Kevin Knupp	UAH	Doppler	1M	1500 nm	0 m
SPARC DL	MP3	Wayne Feltz	U Wisc	Halo Streamline	1M	1500 nm	0 m
Fixed PISA							
ARM DL	FP1	Dave Turner	ARM SPG	Doppler	1M	1500 nm	0 m
ARM MPL	FP1	Dave Turner	ARM SPG	micro-pulse	ANSI Class II	532 nm	0 m
ARM Raman	FP1	Dave Turner	ARM SPG	Raman	Class IV	355 nm	250 m
ALVICE	FP2	Dave Whiteman	NASA GSFC	Raman	Class IV	355 nm	500 m – trying to reduce t distance
MPL	FP2	Belay Demoz/Ruben Delgado	UMBC	micro-pulse	ANSI Class II	532 nm	0 m
WLS200	FP2	Belay Demoz/Ruben Delgado	UMBC	Doppler	?	355	0

GLOW	FP2	Bruce Gentry	NASA-GSFC	Doppler		355	~500m
NPS ceilometer		Qing Wang	NPS	InGaAs diode	1M	910 nm	~10 m
Sigma Space MPL4	FP3	Rich Clark	MU	micro-pulse	ANSI Class II	532 nm	0 m
WLS70	FP3	John Hanesiak	U. Manitoba	Doppler	IEC 60825-1	1540 nm	0 m
Leo 200S	FP6	John Hanesiak	U. Manitoba	Doppler	1M	1540 nm	0 m
Leo EZ	TBD	Trude Storelvmo	Yale	Leosphere EZ lidar	?	355 nm	0 m
Airborne							
LASE	DC-8	Rich Ferrare	NASA LARC	LASE	Class IV	815 nm	NOHD i Nadir: 6 m
WCL-up	UWKA	Zhien Wang	U. Wyo	incoherent backscatter	Class IV	355 nm	65 m
Compact Raman Lidar	UWKA	Zhien Wang	U. Wyo	Raman	Class IV	355 nm	77 m

Q. Acronyms (Salazar)