Plains Elevated Convection at Night (PECAN)

Experimental Design Overview

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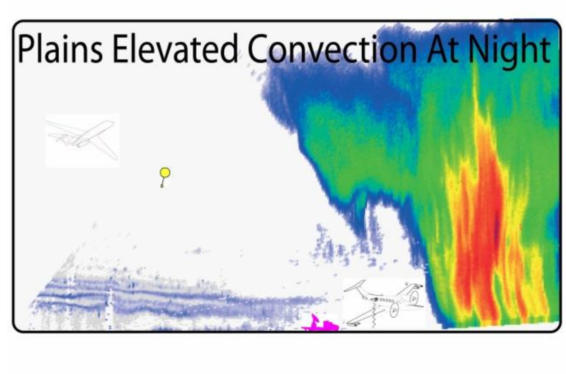

PECAN EDO

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1. Executive summary

The PECAN (*Plains Elevated Convection at Night*) campaign is envisioned as a multi-agency project (NSF, NOAA, NASA, DOE) designed to advance the understanding of continental, nocturnal, warm-season precipitation. PECAN will focus on nocturnal convection in conditions over the Southern Great Plains with a stable boundary layer (SBL), a nocturnal low-level jet (NLLJ) and the largest CAPE (Convectively Available Potential Energy) located above the SBL. Thunderstorms are most common after sunset across this region in summer and much of the resulting precipitation falls from mesoscale convective systems (MCSs). Nocturnal MCSs may produce heavy rainfall; their intensity is correlated with the NLLJ (e.g., Arritt et al. 1997; Tuttle and Davis 2006). To date, an accurate prediction and an in-depth understanding of elevated convection in this environment remains an elusive goal. For example, studies investigating convection initiation (CI) in well-mixed daytime boundary layers have shown that CI often occurs along pre-existing boundaries of surface convergence, evident as radar fine lines (e.g., Weckwerth and Parsons 2006), while nocturnal CI with SBLs over this region is usually elevated (~900 – 600 hPa), often lacks a precursor radar fine line, is poorly understood, and relatively unexplored (e.g., Wilson and Roberts 2006). The question of how the dynamics and microphysics of MCSs evolve as the boundary layer stabilizes in response to nocturnal radiative cooling is also relatively uncertain. Recent scientific studies hold some promise, such as the idealized modeling simulations of Parker (2008) and French and Parker (2010), that propose that the response of convective squall lines to boundary layer stability includes surface decoupling, the potential for intensification of the system and eventually the squall line being maintained by lifting over a bore instead of a surface-based gust front. *PECAN is the first large coordinated effort to study the interrelationship between (1) the initiation of elevated deep convection, (2) the dynamics and microphysics of nocturnal MCSs, and (3) the properties of high-amplitude SBL disturbances.* These results are relevant to the goal of improving numerical weather prediction systems. PECAN's focus on elevated nocturnal convection and on stable layer disturbances distinguishes it from other campaigns that have studied deep convection in the central USA.

PECAN will be conducted in the central Great Plains between 1 June and 15 July 2015. The spatio-temporal domain is chosen based on the climatologies of deep convection, MCSs, NLLJs, and bores, as well as on field deployment considerations and existing facilities, such as the ARM Southern Great Plains site and WSR-88D radars. The PECAN campaign calls for three aircraft: the NSF U. of Wyoming King Air and the NASA DC-8 will probe the pre-convective environment, and the NOAA P-3 will study the microphysical characteristics of developing and mature stratiform regions of MCSs. PECAN will deploy scanning Doppler radars and lidars, radiosonde systems and experimental profiling sensors such as DIfferential Absorption Lidars (DIAL) & Raman lidars, multi-channel microwave radiometers, infrared spectrometers, and acoustic systems. A unique aspect of the experimental design is the incorporation of these profiling systems into the PECAN Integrated Sounding Array (PISA). Each of the 10 PISA units will be highly complementary in their capability to profile wind, thermodynamics, water vapor, and aerosols. PISA's spatial resolution and its variety of remote sensing techniques at widely different frequencies and resolutions makes PECAN particularly well suited to testing goals outlined in two National Academies' reports (NRC 2009; 2010) and the follow-up Tropospheric Profiling Technologies workshop (Hardesty and Hoff 2012). In addition to this broader impact, PECAN research will also impact the nation's NWP capabilities through collaborative efforts between the academic community and NOAA's National Severe Storms Laboratory (NSSL) aimed at assessing the increasing dependence of storm-scale prediction on numerical modeling, as in the Warn-on-Forecast Initiative. NSSL is planning to commit mobile radars and sounding units, with final approval pending NSF's commitment to PECAN. The broader impact of PECAN is further driven by the importance of nocturnal precipitation to the hydrology and agriculture of the region, the public safety risk of MCS-related severe weather, and the applicability to other regions with nocturnal thunderstorm maxima in LLJ environments (e.g., Johnson 2011) and to climate models, which poorly capture the diurnal cycle of precipitation over this region (Pritchard et al. 2011). Finally, numerous students will participate in the data collection and visit the instruments operating in the field campaign.

2. Program rationale

It has long been known that in summer, thunderstorms and convective precipitation are most frequent not in the afternoon, but rather after sunset, in a large swath of the Great Plains ranging from Oklahoma to southern Manitoba/Saskatchewan, and between about 92-100°W (Kincer 1916; Wallace 1975; Easterling and Robinson 1985; Heideman and Fritsch 1988; Colman 1990). For instance, in the state of Iowa lightning is 63% more common at night (03-13 UTC) than during the day, and the surface precipitation rate (convective and stratiform precipitation) is 44% higher at night in summer (Bill Gallus, pers. comm.). Since much of the nocturnal rainfall over these regions is associated with mesoscale organized convection, nocturnal MCSs are critical to the hydrology and agriculture of the region, including over the more arid western Great Plains. These MCSs are also associated with severe weather, including flash flooding, damaging winds, and hail.

What explains this nocturnal peak? Early work focused on mass and moisture convergence associated with the LLJ, which is common over the southern and central Great Plains at night (e.g., Means 1952; Pitchford and London 1962; Hering and Borden 1962). The climatology-based study by Heideman and Fritsch (1988) concluded that "convective feedbacks" were needed to maintain convection over a region becoming devoid of surface-based CAPE. Subsequent studies (e.g., Tripoli and Cotton 1989a, b) suggested that mesoscale convection over this region often has its origin over the Rocky Mountains, which act as an elevated heat source, from which deep-tropospheric gravity waves emerge and propagate, sustaining or triggering nocturnal convective systems over the Plains to the east. Carbone et al. (2002) use composite radar data to reveal diurnally modulated episodes of deep convection propagating from the Rocky Mountains as far east as the Appalachians. One hypothesis is that such propagating convective episodes are sustained by propagating cold pools and emerging bores (Carbone et al. 2002). Or they may be due to gravity wave excitation by deep convection and maintenance by latent heating (Tripoli and Cotton 1989a, b; Tuttle and Davis 2006; Trier et al. 2010). A 3rd hypothesis is that diurnal heating over the elevated terrain of the Rockies generates PV anomalies that persist even in the absence of latent heating while advected over the Plains at night (Li and Smith 2010). The vertical motion associated with these elevated anomalies may trigger convection and maintain MCSs (e.g., Jirak and Cotton 2007).

More recently, convection-permitting models have been used to examine nocturnal MCSs in more detail, including the transition to elevated convection and the formation of a bore (e.g., Parker 2008; French and Parker 2010). This work suggests that an elevated bore can be an integral component of a mature MCS moving through a region with elevated CAPE (i.e., the source level of maximum CAPE is above the surface). Yet gust front driven systems may persist under significant BL stabilization (Parker 2008). Several IHOP-based case studies of bores associated with nocturnal convection over the west-central Great Plains show dramatic net displacement of air in the lower troposphere (e.g., Weckwerth et al. 2004; Whiteman et al. 2006; Knupp 2006; Koch et al. 2008; Marsham et al. 2011). These case studies were all based on chance encounters of bores or solitary waves spawned by outflow boundary density currents.

Nocturnal CI over the IHOP region in 2002 often was associated with synoptic or mesoscale wind convergence or confluence at mid-levels (900-600 hPa), mostly lacking detectable waves or bores (Wilson and Roberts 2006). Yet radar-detected bores were relative common in this region, mostly in western Kansas (Parsons et al. 2013). Both the wave/solitary disturbances and isentropic mass convergence may co-operate, at different scales, to trigger deep convection at night. A lack of observations precludes insight into not only CI mechanisms, but also the evolution of MCSs over a stabilizing BL, as well as the role bores may play in maintaining MCSs that are increasingly decoupled from the surface in the presence of a NLLJ. The coupling of MCS inflows and outflows with the surface generally has remained undetermined because of an inadequate description of the lower-tropospheric environment. For example, if the BL stabilizes significantly below a NLLJ, a turbulence maximum is often present at its top and thus the BL height becomes ill-defined. This BL does not follow the Monin-

Obukhov similarity theory (e.g., Wyngaard 1973; Mahrt 1985). Turbulent vertical exchange across the SBL is largely the result of mesoscale disturbances such as internal gravity waves, density currents, undular bores, solitary waves, and their turbulent collapse (e.g., Sun et al. 2002, 2004; Koch et al. 2008). PECAN will address both how the SBL, the overlying lower troposphere, and the NLLJ wind profile can support and sustain wave disturbances; and how energy is transferred from these disturbances to inertial subrange turbulence. PECAN aims to advance the understanding of the processes that initiate & maintain nocturnal convection in the Great Plains, with a particular interest in the role of stable-layer mesoscale disturbances trapped in the lower troposphere.

Furthermore, several studies will be proposed to use the PECAN dataset to examine quantitative precipitation forecasts (QPFs), and ultimately to improve the treatment of convection in NWP models, which holds promise for improving nocturnal MCS forecasts (Ziegler 1999). Warm-season QPFs are the poorest performance area of forecast systems worldwide (Fritsch and Carbone 2004) which is due in part to the particularly low predictability of nocturnal CI (Davis et al. 2003; Weisman et al 2008). QPF scores are poor both day and night in the Great Plains and only slightly better at night due to the mesoscale organization of nocturnal convection and the lack of the more randomly initiated, short-lived, small-scale convection that prevails during the day (Clark et al. 2007). Model output averaged over the 5-week duration of the 2010 NSSL-SPC Hazardous Weather Testbed (HWT-2010) for the convection-allowing (4-km grid) ensemble model runs (**Fig. 2.1**) reveals significant errors in CI, system duration, and QPF, in particular during the night (forecast hours 02-11 and 26-30) in the PECAN longitude belt. Clearly this assessment is preliminary as accuracy depends on initial time, microphysics scheme, and model resolution. The HWT-2010 analysis also finds that correlated biases of both MCS position and the forecast precipitation amounts are quite sensitive to the microphysics scheme used (Clark et al. 2012). Hence detailed microphysical measurements in PECAN, both *in situ* (airborne particle probes) and remote (multi-wavelength, dual-polarization radar), are essential.

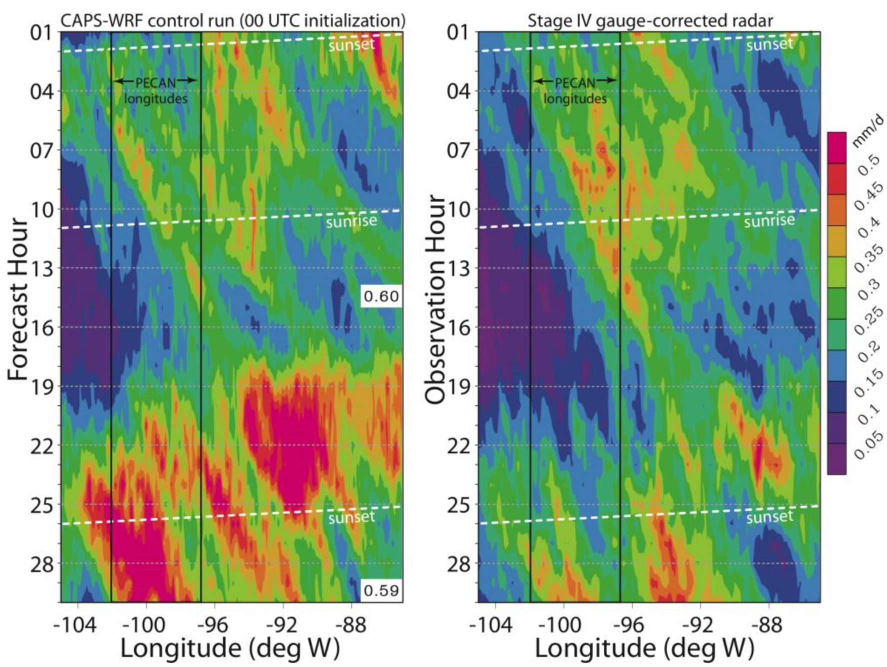


Fig. 2.1: QPF evaluation for a 5-week HWT-2010 period in late spring 2010 in the central USA. Values represent the average precipitation rate within the 30-49° latitude belt. The left panel is the CAPS WRF control run with Thompson microphysics (Clark et al. 2012). The right panel is the Stage IV gauge-corrected radar precipitation. The observed patterns in the 1-6 hour time frame do not repeat in the 25-30 hour because the model was run only on weekdays. (analysis courtesy Adam Clark-NSSL)

PECAN is also relevant to advancing climate modeling, since the representation of propagating nocturnal MCSs in such models remains elusive (Pritchard et al. 2011; Anderson and Correia 2013), especially in models that parameterize deep convection. Invariably progress in the representation of the diurnal cycle of continental precipitation must be made first in NWP models, upon which this knowledge can be transferred to the climate community (Brunet et al. 2010). The proposed research has implications beyond the North American Great Plains, since nocturnal (and thus possibly elevated) thunderstorms frequent other continental regions, such as subtropical South America east of the Andes and the Sahel/Savanna belt of northern Africa (Dai 2001; Nesbitt and Zipser 2003; Geerts and Dejene 2004).

No large field campaign has focused on the initiation and maintenance of deep convection that is more or less decoupled from the surface during at least part of its life cycle. Certain field campaigns such as IHOP (2002) and BAMEX (2003) have had tantalizing observations of relevance and motivation to PECAN. However, IHOP focused on the daytime convective boundary layer and lacked sufficient soundings at night. BAMEX focused on specific aspects of high-end MCSs, such as bow echoes and mesoscale convective vortices (neither of which are studied in PECAN) in a rather moist low-level environment generally lacking a LLJ and a SBL.

3. Scientific objectives and hypotheses

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:

I. Nocturnal convection is more likely to be initiated and sustained when it occurs in a region of mesoscale convergence above the SBL.

II. 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.

III. 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.

IV. 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.

4. Experimental design and observational requirements

4.1 Pinpointing the field phase: where, when, and how long?

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. 4.1**). 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. 4.1). 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. 4.2**) occurs on average every other night within the black box in Fig. 4.1. Substantial intra-seasonal (week-to-week) and more limited interannual (±35%) variability exist within this box (Fig. 4.2). Nocturnal heavy precipitation is most common in the month of June within the box in Fig. 4.1, but there is no statistically significant trend in the typical number of targetable heavy precipitation events between early June and late July (Fig. 4.2). 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 3) 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 to 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. 4.3**).

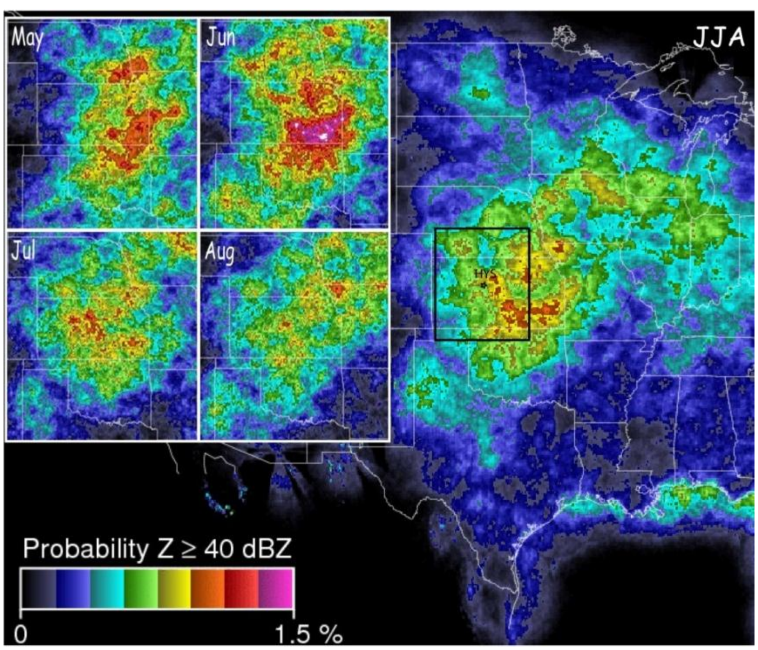


Fig. 4.1: Probability of radar reflectivity values exceeding 40 dBZ during the night, between 3:00 and 11:45 UTC, in the warm season (JJA), based on national WSR-88D composite 2x2 km^2 grid maps from 1996 to 2007 made every 15 min by WSI. The inset panels show the same, for the months of May to August. 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)

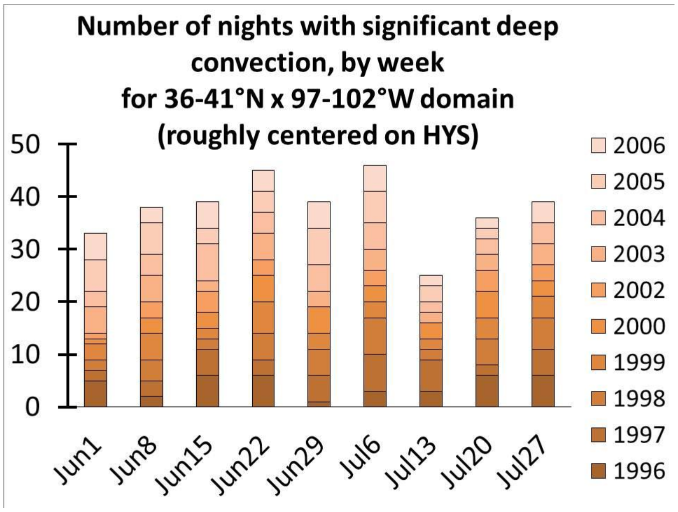


Fig. 4.2: Number of nights (0300-1200 UTC) per week that a radar reflectivity value of at least 50 dBZ was encountered in at least 2% (roughly 200 km^2, not necessarily a contiguous area) of the 5°x5° box centered on HYS (shown as a black box in Fig. 4.1) in June & July, based on 10 years of WSR-88D 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. 4.3: 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. 4.4**). Note that Fig. 4.4 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. 4.5**, 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. 4.3). 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. 4.3). 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.

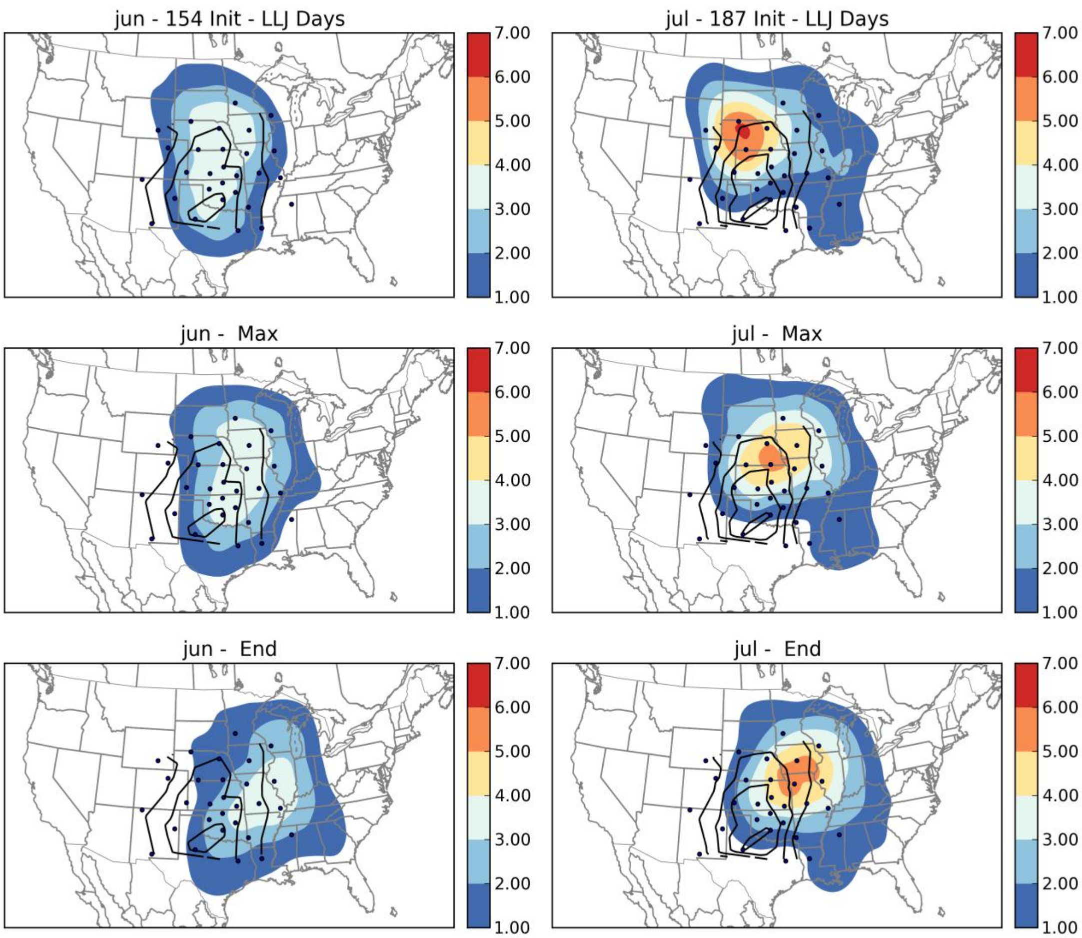


Fig. 4.3: Spatial distribution of large, long-lived MCSs at the time of MCS initiation (top), maximum extent (middle), and decay (bottom) in June (left) and July (right), as derived from the "NSSL MCS climatology" combining Gaussian kernel density estimation (KDE) and MCS-centroid locations (see text 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).

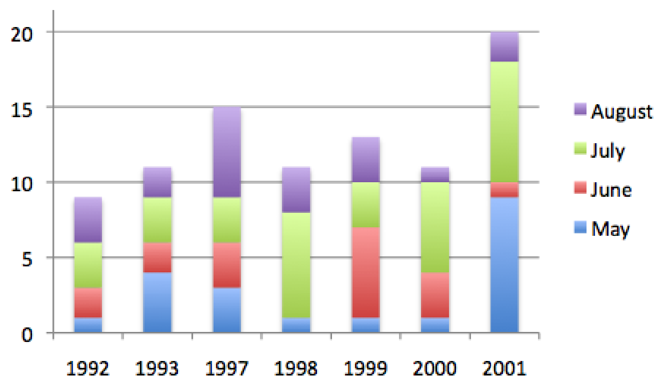
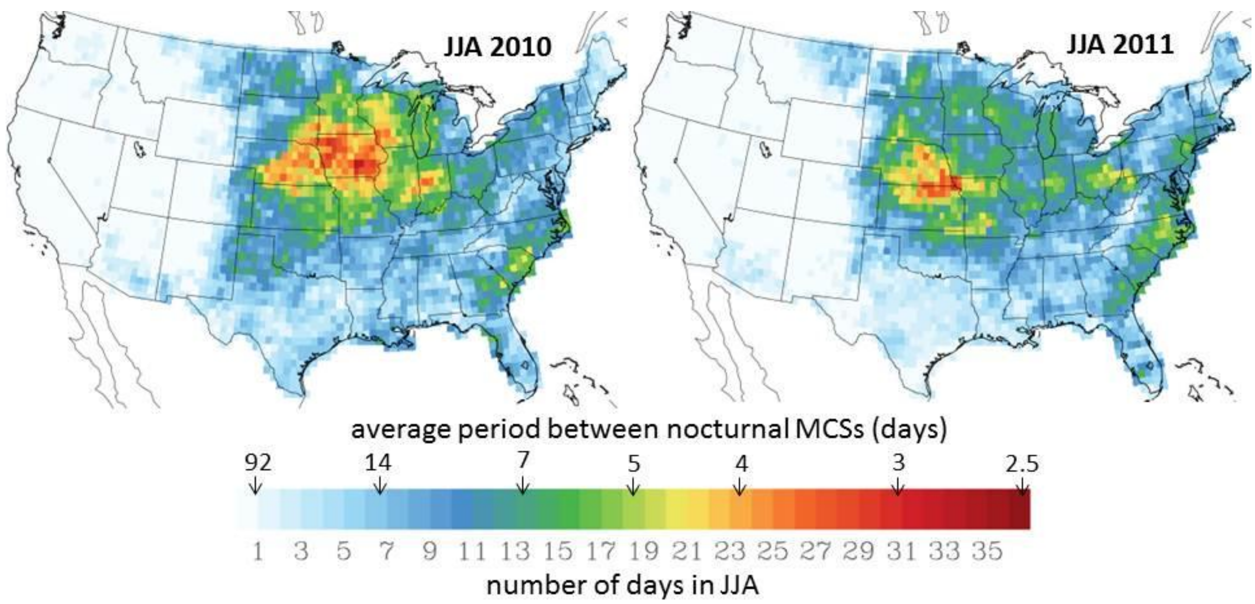


Fig. 4.4: The number of MCSs crossing the nominal PECAN domain (corresponding roughly to the 5°x5° box in Fig. 4.1) in the 7 years of the NSSL MCS climatology used for Fig. 4.3. Only systems with more than 150 km of track length and with a maximum-extent stage occurring in the period 03 - 12 UTC are included. (Analysis courtesy of Conrad Ziegler and colleagues at NSSL)



Nocturnal MCS frequency. Nocturnal is defined as between 6pm – 6 am local solar time. An MCS is defined as a contiguous area with reflectivity > 40 dBZ over a length of >100 km.

Fig. 4.5: 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 4.1), 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. 4.6**), 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. 4.1, 4.3, 4.5). 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.

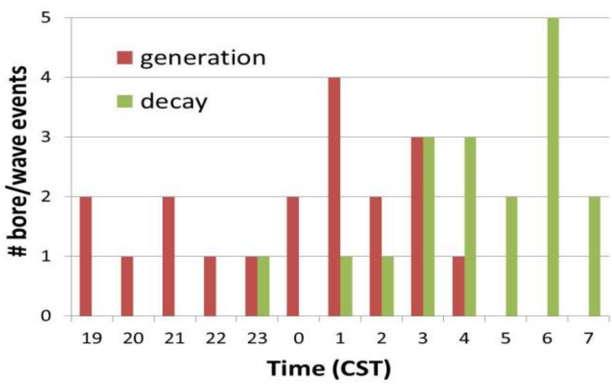


Fig. 4.6: Diurnal pattern of bore generation and decay based on S-Pol and WSR-88D data in the IHOP (13 May – 30 June 2002) domain, which includes western Kansas and Oklahoma, and the Texas Panhandle. The events earliest in the diurnal cycle had characteristics similar to those predicted by Liu and Moncrieff (2000) and thus were difficult to distinguish from density currents. (image courtesy of Dave Parsons - OU)

D. PECAN IOPs and field phase duration

We propose a PECAN field phase from 1 June to 15 July 2015 (45 days). The time of year is fairly inflexible, given the climatological considerations discussed above. 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 (Section 5). 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 (Section 4.1.B) 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. 4.3). 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. 4.5) 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. 4.2). 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*.

4.2 Instruments and instrument platforms

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:

I. 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;
II. The evolution of the lower-tropospheric wind and turbulence profiles, in order to quantify moisture transport, mesoscale convergence, and NLLJ-SBL interactions;
III. 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*,
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 **Table 4.1**. All units are currently in operation or deployment-ready, except three (the top-listed components of FP3 and MP1, and the mini-DIALs), which are in the development stage and will all be field-tested in 2013. 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- & C-band radars (Section 4.2B below). The Howard/Millersville 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, possibly a 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. We are requesting 3 of these "mini-DIALs", one each at FP3, FP4, and FP5. One mini-DIAL is being tested and upgraded, and we can reasonably expect 3 units to be field-ready by 2015. 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, a MR on lease from Radiometrics Inc, and a mini-DIAL. The Naval Postgraduate School proposes to deploy a tethersonde profiling system, a rawinsonde, a mini-sodar, and a tower-based flux system at the FP4 site. Finally, **FP6** consists of a MR, a wind lidar, and an AERI from the University of Manitoba. 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, an 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 final mobile unit (**MP4**) is the NCAR EOL Mobile ISS (MISS). Two AERI units (one for FP3, one for MP4) will be requested from DOE (PI: David Turner).

ii. ***Fixed and mobile ground-based radiosonde systems***

Six university-provided radiosonde units will be deployed as part of PISA (Table 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 hope to obtain 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. A letter of DOE support for PECAN is attached. 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.

ID	lead PI	instrument source	instruments
fixed profiling units (FP): stationary during the duration of PECAN, operating continuously			
FP1	David Turner	ARM CART Central Facility	wind lidar, Raman lidar, AERI, MR, sfc met and sfc fluxes, radiosonde unit, four 915 MHz WPs with a typical spacing of 10 km
FP2	Rich Clark + Belay Demoz	Millersville Univ.	1000 m tethersonde profiles of met variables/turbulence, sfc met and sfc fluxes, backscatter lidar, radiosonde unit, and sodar
		Howard Univ. and NASA/GSFC	ALVICE Raman lidar & GLOW and/or Leosphere wind lidars, MR
FP3	David Parsons + Volker Wulfmeyer	NCAR EOL	ISS-449, mini DIAL
		U. Hohenheim, Germany	scanning DIAL (water vapor) and scanning rotational Raman lidar (temperature)
		Colorado State U.	radiosonde unit
		Univ. of Manitoba	MR and wind lidar
FP4	Tammy Weckwerth	NCAR EOL	ISS with 915 MHz WP, mini DIAL, GAUS, sfc met
		Radiometrics	MR
		Naval Postgrad School	flux tower, sodar, tethersonde
FP5	Tammy Weckwerth	NCAR EOL	ISS with 915 MHz WP, sodar, mini DIAL, GAUS, sfc met
		Radiometrics	MR
FP6	John Hanesiak	Univ. of Manitoba	MR, wind lidar, AERI
		DOE	radiosonde unit & sfc met (ARM SPG Larned site)
mobile profiling units (MP): operate during IOPs only			
MP1	David Turner	U. Oklahoma, NSSL	CLAMPS: AERI, MR, and scanning Doppler lidar
		U. Oklahoma	radiosonde & sfc met
MP2	Kevin Knupp	Univ. of Alabama Huntsville MIPS truck	scanning Doppler lidar, 915 MHz WP, MR, sodar, ceilometer, sfc met, radiosonde unit
MP3	David Parsons, H. Bluestein, Wayne Feltz	Naval Postgrad School	TWOLF Doppler lidar & FM-CW radar (both truck-mounted) + sfc met
		U. Wisconsin	AERI + multi-spectral aerosol lidar + radiosonde unit
MP4	T. Weckwerth	NCAR EOL	Mobile ISS with 915 MHz WP, MGAUS, sfc met

Table 4.1: Proposed PISA units. Note: "sfc met" = surface meteorological measurements. The red-highlighted instruments are part of the NSF LAOF deployment pool.

B. Radar systems

i. ***Mobile radars***

Several ground-based mobile radars will be used to detect bore disturbances and the NLLJ, obtain MCS-scale and storm-scale kinematic observations, and to estimate microphysical properties. The mobile radars will be pre-deployed either upwind, into the path of an MCS, or in a region with a significant probability of elevated CI (Section 4.3). PECAN proposes to deploy a spatially extensive mobile radar array that will deploy once and remain fixed as the target weather systems move and evolve within the array coverage. The mobile radars will be deployed in an array configuration that provides an optimal balance of areal and 3-D volume coverage, spatial resolution, and accuracy of synthesized multi-Doppler winds. Several of the mobile radars and/or their Scout 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 and to 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). The radars are described briefly below. Details can be found elsewhere in the literature.

a. Storm surveillance Doppler capability

For the MCS and bore IOPs, wind analyses must 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 most resistant to attenuation, resulting in a deeper penetrating range through heavy precipitating systems. The C-band SMART-radars, one of them 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 up to five X-band mobile radars (two dual-pol DOWs, the Rapid-Scan DOW, NOXP, and MAX). Radars will be arrayed via series of triangles with baselines of 35-45 km, thus reducing potential X-band interference while also increasing coverage. Finally, a rapid-scan X-band mobile radar (RAXPOL) will be deployed in close proximity to MP3 (Table 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) will be utilized to augment the multiple-Doppler radar coverage of storm features while simultaneously obtaining polarimetric data.

ii. ***Fixed radars***

a. S-PolKa

The NCAR S-PolKa 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. If suitable the RHI will be pointed towards FP3 to the south (Fig. 4.7), to interpret the radar data in the context of the thermodynamic profile. 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.

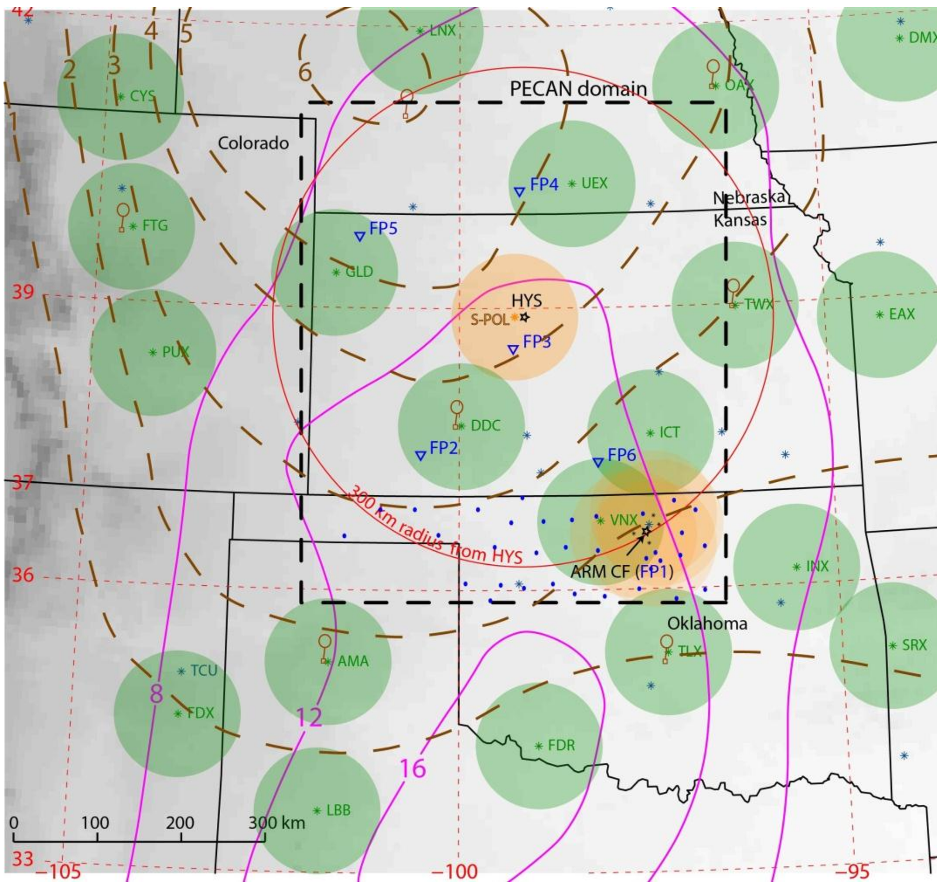


Fig. 4.7: *Location of the PECAN domain (bold dashed line) in the Great Plains. Also shown are the operational radar networks (WSR-88D and ARM SGP), the fixed PECAN radar and PISA facilities, and climatological information (frequencies of NLLJ and of early-stage large MCSs, from Fig. 4.3). The radar 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-PolKa has five additional benefits to those listed above:

1. It is unclear whether the vertical structure of nocturnal fine-lines (in an RHI) shows 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-PolKa 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. The dual-frequency S-Ka bands of S-PolKa will be used to obtain clear-air humidity and in-cloud

liquid water profiles which will be valuable in characterizing the pre-convective and MCS environments.

5. S-PolKa will fill a gap in the WSR-88D coverage near Hays, KS (Fig. 4.7).

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. 4.7). Less-known is the small network of fixed, dual-polarized C- and X-band Doppler radars and a Ka/W band scanning cloud radar at the ARM SGP Central Facility. This dataset with fixed scanning strategies is freely available and will 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. Either a proposed temperature-humidity Raman lidar, or a less powerful humidity-only 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 10 km MSL. 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% across the troposphere (Browell et al. 1997). Plans are in progress for the DC-8 to also deploy a scanning interferometer, either the NASA Langley Research Center NPOESS Airborne Sounding Testbed – Interferometer (NAST-I), or the U. Wisconsin Space Science and Engineering Center (SSEC) Scanning High-resolution Interferometer Sounder (S-HIS) instrument. Both are scanning interferometers that measure thermal radiation at high spectral resolution between about 3 to 16 micrometers. The upwelling spectral radiances are used to obtain temperature and water vapor profiles over a cross-track swath width of approximately 20 km. 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 (Section 4.3). If the DC-8 becomes unavailable for PECAN, the NASA P-3 may serve as an alternate platform for the LASE and possibly for a scanning interferometer. This P-3 will be able to fly in closer proximity to the MCSs.

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).

iv. ***Center for Interdisciplinary Remotely-Piloted Aircraft Studies & South Dakota School of Mines and Technology A-10 (NSF)***

In response to a separate expression of interest, NSF has asked us to consider the deployment of the CIRPAS / SDSMT A-10 storm-penetrating aircraft during PECAN to target the convective portions of MCSs that the NOAA P-3 will avoid. The A-10 would be a welcome addition via its unique *in situ* measurements of precipitation particle size distributions, thermodynamic and kinematic fields. At this time the Science Steering Committee (SSC) will not request the A-10 for PECAN due to uncertainties with instrument readiness and its ability to safely operate in deep convection at night. We would, however, welcome the participation of the A-10 in a "piggy-back experiment" as it would assist in achieving several PECAN MCS objectives.

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 (Section 4.3).

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 4.2**.

		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-PolKa	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
aircraft	UWKA with WCL & RL	X	X	X
	NASA DC-8 with LASE & interferometer	X	X	X
	NOAA P-3 with tail radar			X

Table 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 (Section 4.2.A.i). Some uncertainty remains about the shorter-wavelength radars to capture air motions and layer vertical displacements associated with SBL wave disturbances (Section 4.3.D).

4.3 Field deployment strategy

A. Fixed sites

The PECAN domain encompasses central and western Kansas, as well as adjacent parts of mainly Nebraska and Oklahoma (**Fig. 4.7**). Its location is driven by climatological information (Section 4.1). Its size is determined by the maximum driving distance from Hays, KS, about 350 km, for mobile units in anticipation of an IOP. Its N-S elongated shape is explained by persistent meridional variations in MCS tracks, and by accessibility and site quality for mobile ground-based scanning systems. The PECAN domain has reasonable low-level radar coverage (a 0.5° elevation radar beam is ~1.2 km above radar elevation at a range of 75 km), mainly in the southeastern sector on account of the ARM radars. Coverage is lacking in the central PECAN domain near HYS, which affected our choice to locate S-PolKa near HYS. The fixed PISA (FP) units are distributed in the domain at a typical spacing of 200 km, and each is within 75 km of at least one S-band radar. The reason is that the FPs and the S-band radars will operate 24/7 during PECAN, thus providing a rich dataset also capturing the afternoon-evening transition (AET) and morning transition periods. The southern FPs are more likely to "participate" in bore missions, the western FPs in CI missions, and the eastern FPs in MCS missions.

B. Convection initiation missions

The CI missions initially will target regions of mesoscale convergence above the SBL (**Fig. 4.8**). In some cases CI is expected on the cold side of a low-level synoptic baroclinic zone, within the exit region of the elevated NLLJ, as in Fig. 4.8. In other cases a baroclinic zone will be absent. The optimal deployment of 7 mobile radars is in a hexagonal array with one radar in the hexagon's center. The mobile soundings and PISA units are positioned to allow for Bellamy Triangle calculations of basic kinematic fields (Bellamy 1949; Spencer et al. 2003). The exact facility layout will differ somewhat, depending on the density of pre-selected sites. The mobile PISA units are deployed along a line normal to the convergence line, at a spacing of ~35 km. The UWKA and the DC-8 fly racetracks across the pre-convective convergence line. The UWKA racetrack initially will be ~100 km long, the DC-8 track 200-300 km. If a well-defined convergence line is encountered, the racetrack will be shrunk. In case of CI, sampling will continue for a period of 1-2 hours to quantify the upscale growth process toward an MCS stage, but only if the system is slow-moving. Mobile observations will continue as long as useful, but the PECAN array will not be repositioned to track the possible upscale growth from isolated deep convection to MCS initiation, given the typical time and space scales of such growth.

C. MCS missions

In an MCS mission mobile units are deployed ahead of a recently formed MCS that is predicted to be long-lived (**Fig. 4.9**). The mobile radars assume a hexagonal pattern with the C-band radars closest to the approaching MCS. The mobile PISA units are positioned along the line of MCS centroid migration, with a characteristic spacing of 35 km between units. The RAXPOL radar will be deployed in close proximity to MP3. The UWKA will fly across the outflow boundary in a square tooth pattern with boundary-normal legs about 50 km long, mainly covering the multiple Doppler hexagon. Once a bore/wave structure is encountered, a narrow racetrack with leg length about 50 km will be flown, to capture the evolution of the structure at flight levels ranging between 1000 ft AGL and 3 km MSL. The DC-8 flies an equally narrow racetrack pattern normal to the outflow boundary, with one of the legs corresponding with the line of MP units. Narrow racetracks maximize time resolution as return visits are faster than a 90-270° turn, and along-wave uniformity can be assumed over a short lateral displacement. The NOAA P-3 will penetrate the stratiform and transition regions of the MCS, with spiraling descents and ascents at flight levels ranging between 0.3 and 6 km AGL. The P-3's flight levels are shown in the insert in Fig. 4.9. One leg at a level of ~5 km follows the length of the squall line in the transition region under guidance of real-time lower-fuselage radar reflectivity imagery. The P-3 flight pattern improves on experience gained in BAMEX by greatly increasing the number of spiral ascent and descent maneuvers to better profile the rain and ice regions of target MCSs.

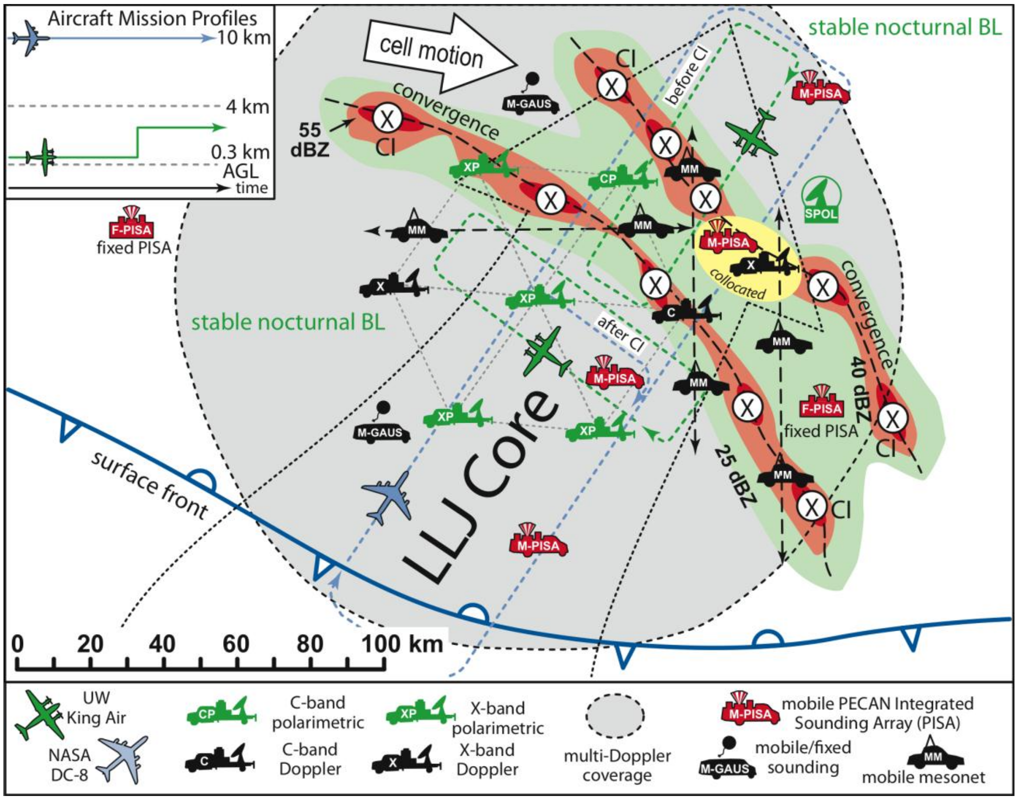


Fig. 4.8: CI deployment strategy. The mission starts well before anticipated CI, based on model and human forecast guidance, and flight operations are subsequently modified to sample the convection-relative inflow area and NLLJ (if present) during the post-CI period. Radars and PISA units remain in a fixed deployment, with some pre-CI adjustment possible based on real-time evidence for pre-existing convergence lines. RAXPOL and MP3 are collocated.

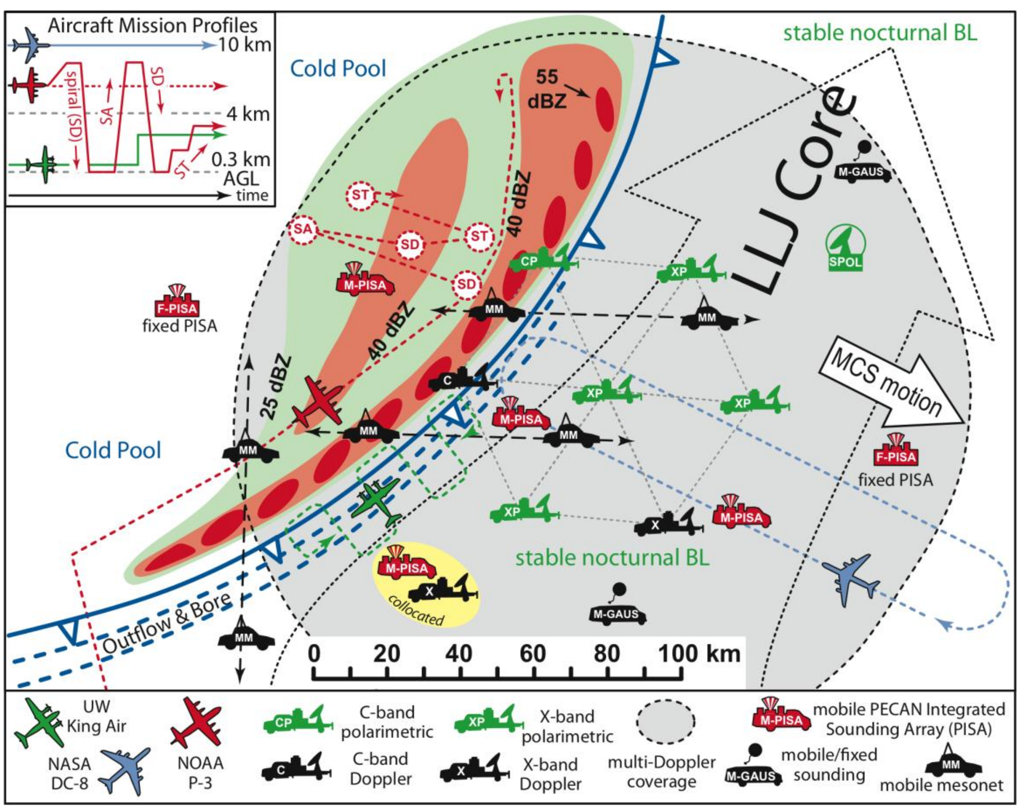


Fig. 4.9: MCS deployment strategy. The mission starts around the time that widespread convective storms have developed and begun clustering (given forecasts indicating a high likelihood of conditions supporting development of persistent MCSs given widespread storms). Radars and PISAs remain in a fixed deployment, while other mobile platforms adjust for system motion. In the insert, SD=spiral descent, SA=spiral ascent, ST=stepped traverse.

D. Bore missions

The bore missions are designed to determine why bores form, how they evolve, how they interact with the environment and how they influence convection. The bore missions will target the southern and southeastern regions of MCSs (**Fig. 4.10**). While bores are equally likely to emanate outward in other directions, the bores with a more zonal orientation favor a continuation of convective activity north of the bore likely due to favorable MCS inflow produced from the interaction between the NLLJ and the ascent produced by the bore. The DC-8 with LASE is important to map out the large-scale environmental moisture field and detect the net upward displacement by the bores. The UWKA will also profile the bore, but at a higher frequency, and provide *in situ* thermodynamic and kinematic information between 1000 ft AGL and 3 km MSL. Mobile soundings and profiles from the fixed and mobile PISAs in advance of and during passage of bores are critical to sampling the vertical profiles of wind and stability in the lower troposphere in advance of the bores, as well as the bore structure. This data will be used to determine how the bore ascent modifies the air to feeding into the trailing convection or MCS. The fixed and mobile radars will help to determine the relationship between the bores and the structure of the trailing convection including the generation of new cells and new convective outflows. Mobile radar clear-air signals (mostly due to insects) will be used to observe the bore structure, scale, horizontal and vertical extent. Nocturnal insects tend to be strong flyers (Drake and Reynolds 2012). Doppler lidar velocities and layer vertical displacements are not affected by insects. Therefore the RAXPOL radar will be collocated with MP3 for the bore missions (Fig. 4.10) and in other clear-air situations (Figs. 4.8, 4.9) to distinguish insect horizontal motion and (in the presence of a bore) the likely opposing vertical motion of insects, which leads to an underestimation of the isentropic vertical displacement.

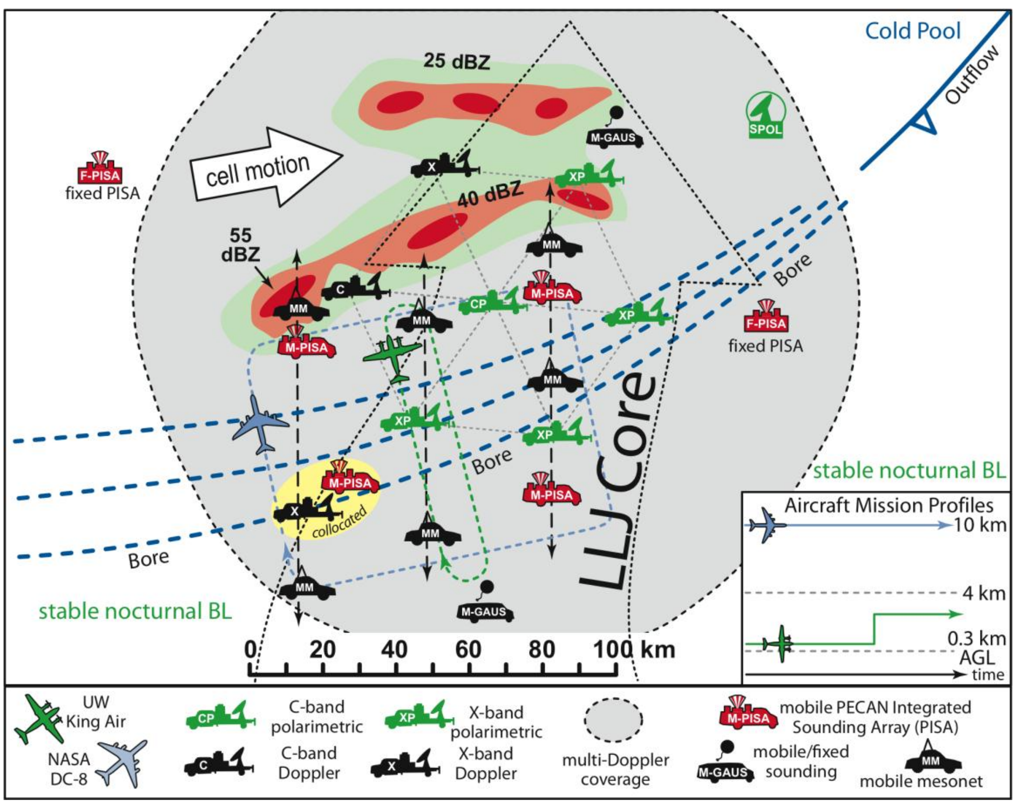


Fig. 4.10: Bore mission deployment strategy. The same hexagon mobile radar array is used, and M-PISA units are positioned to optimize bore passage sampling in the multi-Doppler domain. The mission starts before bore emergence based on MCS occurrence. In case S-Pol is close to the target bore, one of the MPs with Doppler scanning lidars (MP1-MP3) will be collocated with S-Pol to compare S-band radar to lidar coverage of bore vertical displacements.

5. Project and field management

5.1 Project planning

i. *Project planning coordination and site selection*

PECAN will require an extensive support network and well-considered plan for effective communications and operations implementation. The PECAN deployment is complex due to several factors; the main one regards the deployment in potentially inclement weather at night. All planning and implementation of the observing facilities must take into account the challenges and safety considerations of night-time operations in potentially severe weather conditions.

The PECAN SSC requests support from NCAR's Earth Observing Laboratory (EOL) in areas related to project planning, field operations support and data management. The project will ask EOL to participate in planning discussions and meetings, and to assist with the preparation of the PECAN Operations and Data Management Plans. Critical tasks in the period before the field deployment will include the refinement of aircraft deployment strategies, coordination between aircraft facilities and FAA/ATC, and development of a detailed mission planning process.

The PECAN SSC also requests EOL support to conduct a pre-selection of candidate sites, aimed at safe and efficient operation of the mobile units (radars, sounding units, and PISAs) at night. This selection process should start at an early stage of the PECAN project planning phase. A density of one site roughly every 20 km spanning the 400 km x 500 km PECAN domain (Fig. 4.7) corresponds to about 500 sites. Site density and placement should be broadly consistent with the mobile facility deployment diagrams shown in Figures 4.8-4.10 (e.g., approximating a proposed triangular mobile radar array element). A virtual process for identifying candidate sites could be conducted using readily available tools in a land-surface GIS-based interactive on-line service (e.g., Google Map with "Street View"). Additional useful location data regarding potential sites in the PECAN domain may be obtained from metadata and the Situational Awareness for Severe Storm Intercept (SASSI) radar-deployment site markers contained in the VORTEX2 (2009-2010) archive. Individual pre-selected sites will be vetted prior to the field phase via a subsequent follow-up "grand road tour" of the PECAN domain, with a special focus on access and obstacles obstructing low-elevation scans. This GIS-based site quality data set would be displayed in either SASSI or EOL Catalog Map by the mobile ground-based teams and coordinators to facilitate nocturnal deployments during PECAN, and also would represent a good investment for use in future NSF-supported field projects in the central Great Plains.

PECAN project planning and field support responsibilities will include coordinating all ground-based facilities, coordinating project aircraft activities and FAA interactions, project communication, in-field and post-project data management, and collaborative development of a mission planning process. Appropriate EOL staff will be invited to participate in aircraft base site selection and logistics planning to help ensure maximum and efficient scientific return with a reasonable cost.

ii. *PECAN Operation Center*

Hays, KS is the most likely Operations Center (OC) and home base for mobile and fixed ground-based operations, based on currently available information, including climatology (Section 4.1), accessibility, and local logistics. The most suitable base for the UWKA is KSLN (Salina, KS) with which EOL has gained extensive experience in the DC3 field campaign. The NASA DC-8 and NOAA P-3 will be based at Will Rogers Airport (KOKC) to minimize overall staffing costs, providing one-way ferry access to any point within the PECAN domain within about 1.5 hours (e.g., flight time to central NE). The investigators will work with EOL and the aircraft and ground facilities to finalize the base of facility operations and coordination. There is some advantage for all teams to be collocated, but there are overriding arguments related to integrated driving time and hangar facilities, and telecommunication has become easy and powerful.

5.2 Field coordination and support

It is proposed that EOL provide an OC at the location of the mobile and fixed ground-based operations and assist in real-time coordination of PECAN research activities during field operations. Aircraft facilities should participate in OC activities via some combination of video teleconferencing and/or on-site representatives. The OC activities will include daily project planning meetings (with many attendees interacting remotely) and operations support activities through the dissemination of critical project planning information. Coordination of ground-based mobile and airborne assets will be initiated at the OC to maximize flexibility in sampling location and strategies. As noted above, PECAN offers an additional complexity that aircraft and ground based data collections will normally occur at night. Communication and display capabilities such as the EOL Field Catalog customized for PECAN (see section 6), SASSI (section 5.1), internet chat-rooms, real-time product display and overlay capabilities at the OC, aboard the aircraft and in the field assets may also be requested and hopefully implemented as part of the OC. These will be invaluable for the successful coordination of airborne assets, ground-based mobile facilities and sounding launches. When the aircraft are deployed, the primary aircraft-to-ground communication channel and decision pathway will be through OC.

Dedicated forecast and nowcast guidance will be provided by 1-2 NSSL staff, and/or by PECAN participants such as Bill Gallus. Specific ingredients-based AWIPS-II scripts will be developed and tested in advance, in support of the three mission types, i.e. CI, bores, and MCSs. Both operational models and PECAN-specific simulations by CAPS (see one-page statement from Xugang Wang in the SPO) will be used. PECAN data, especially the soundings, will be incorporated in the datastream for assimilation into these models.

It is proposed that the PECAN OC will coordinate all project flight planning contacts with all air traffic centers during the field campaign. PECAN requires advance planning and coordination for all aircraft missions to operate on a non-interference basis with local and regional FAA air traffic patterns and Military Operations Areas (MOAs). This will begin with meetings and briefings at affected FAA Air Traffic Centers and military districts in advance of the field deployment and will involve project personnel and platform pilots. This activity will be coordinated between the UWKA, NASA DC-8 and NOAA P-3 flight personnel. Flight operations conducted over ground sites will fall within the domain of the following FAA Air Route Traffic Control Centers: 1) Denver (Northeastern Colorado); 2) Kansas City, Albuquerque and Memphis (central- southern Oklahoma, Texas Panhandle and west Texas); and 3) Minneapolis (N Kansas, S Nebraska). Procedures will be established to meet FAA requirements for receiving proposed project flight operations alerts and requests. This will involve advanced notifications, graphical depictions of affected areas, aircraft flight plans, and consideration of the timing of each facility’s flight operations. For maximum probability of success, we want to be able to update flight plan details based on changing weather conditions. PECAN anticipates having to be flexible about the location and maneuverability of project aircraft, especially as proposed flight plans are likely to intersect known operational airways and restricted military operations areas. The project will rely on the experience of platform pilots and EOL aircraft coordinators to assist in this planning.

In the field, decisions must be made on a daily basis as to which location has a reasonable probability of developing MCSs and CI that can be targeted for study. The decisions must be made far enough in advance so that the mobile ground assets can get into position to collect needed data (Figs. 4.2 and 4.3) and so that proper coordination with ATC authorities can be accomplished. These decisions are to be based on the following: evaluation of weather forecasts (presented by the forecasting team either in person or by video-teleconference); real-time evaluation of information from radars, satellites, and other real-time operational observing systems; evaluation of the readiness of the aircraft and ground-based mobile facilities in consultation with the facility managers; and consideration of appropriate balance between the nocturnal MCS, bores and elevated CI themes needed to address the overall scientific objectives of the experiment.

The proposed daily operations timeline is shown in **Fig. 5.1**. This timetable will be strictly adhered to so participants can develop regular sleep patterns. Prior to 17 CDT daily, a deployment team consisting of PIs, forecasters, facility managers, operations coordinators and instrument representatives will meet to assess the latest forecast and discuss operational plans for the current night ("Night 1") and the next night ("Night 2"). At this time, an essentially final decision will be made whether or not to deploy the ground-based mobile and airborne facilities during Night 1. The mission scientists will meet with the pilots to finalize flight plans, and approximate takeoff times will be selected. If a targeted MCS or CI does not develop as predicted, a decision will be made to abort the deployment, and for the mobile crew to either seek local accommodation, or return to base, depending on the Night 2 forecast and distance from base. In fact the mobile ground crew may stay in a less-centered part of the PECAN domain for a several days in a row, should synoptic conditions favor this. It is expected that PECAN will obtain at least 12 IOP events that use all ground-based mobile and airborne facilities and 90-min interval soundings from the PISA sites.

While the aircraft are deployed, there will be continual communication between the mission scientists for each aircraft, the local ground-based radar scientist at S-PolKa and/or the OC, and the other ground-based members of the deployment team. They will regularly review the status of the deployment and make recommendations for the optimum observation strategy. During this time, however, the individual aircraft, through consultation between the mission scientist and pilots, will be responsible for their own flight tracks and safety. Similarly, during this time the mobile ground-based team leaders will be responsible for following their individual pre-defined assignments and monitoring their team's operations and safety. The PECAN investigators note that there will actually be increased flexibility in aircraft operations at least related to other air traffic because of the focus on nocturnal events. This is likely to be particularly true in MOAs.

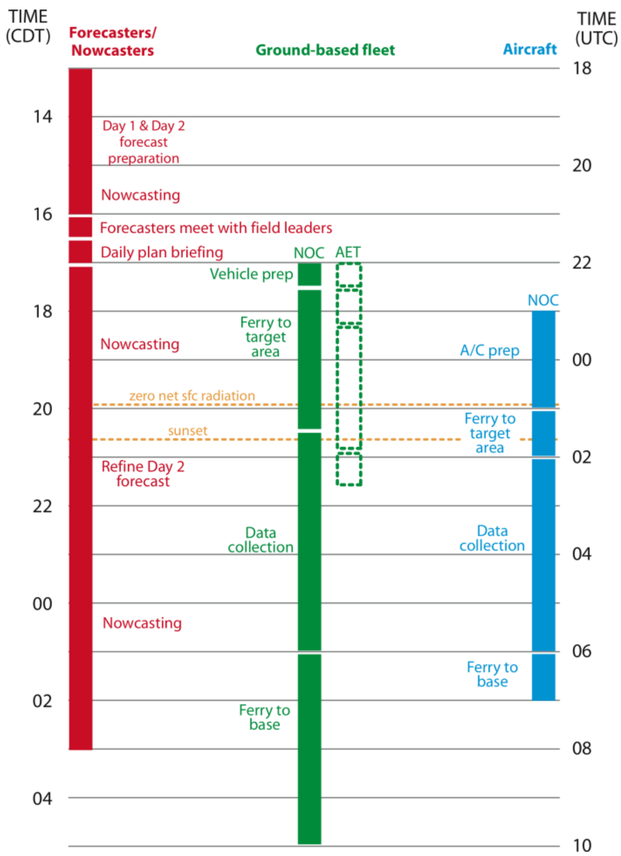


Fig. 5.1: Proposed conceptual timeline relating the forecasting and nowcasting activities to the ground-based mobile and aircraft operations during PECAN. Many fixed PECAN facilities operate on a semi-continuous basis and thus are not represented. The actual beginning and ending times of the mobile ground-based and aircraft operations during any given IOP may vary by up to O (± ½ hour), depending on the anticipated timing of either nocturnal CI or MCS and bore development ("NOC") or an afternoon-evening transition ("AET") event and detailed objectives of that IOP.

Careful project planning to provide adequate crew rest between missions is a priority for safe and effective ground-based and airborne PECAN nocturnal operations. FAA rules limit the amount of time aircraft crews can work per day, per week and per month. These limitations will be part of the consideration in planning upcoming missions. EOL will be asked to provide a project manager to help interface between the science team and the aircraft crew. Due to the unique challenges of safe ground-based operations on public roads at night (and often after inclement weather) combined with the unusual work schedule which requires sleeping during the day, building in adequate time for resting teams is essential. It is possible that ground crews may sometimes get hotel rooms near their deployment sites if it is deemed too far or too hazardous for them to drive back to Hays. It is anticipated that mobile ground-based teams would participate in driver safety and CPR training courses prior to the field phase (as e.g., VORTEX2).

5.3 General project management issues

The principal investigators are primarily responsible for the organization and oversight of PECAN. Together they make the decisions concerning the platforms and facilities requested for the campaign, as well as decisions regarding the day-to-day during the field campaign. All of these decisions are made after input is received from the PECAN SSC via regular meetings and communications, and by interested members of the scientific community through focused workshops. Two workshops were conducted in 2011, in Boulder and at the Pittsburgh Radar Conference, and since then several phone conferences and smaller meetings have been held. If approved, planning workshops approximately every 6 months would continue until the project commences. The workshops will shift emphasis from science issues to operational implementation issues as we approach the field phase. The workshops tend to yield general recommendations; the SSC makes more specific recommendations with pros and cons of each side; and the PIs make the decisions and take the actions necessary to carry them out. The PIs and PECAN SSC members are listed on the cover page of this document. Once we are in the field the science team and SSC will make day-to-day decisions regarding the specific science objectives for a given event or intensive observing period. It is the job of the operations support staff to carry out the wishes of the science team in an effective and safe manner.

In a domestic project such as PECAN, there will be many requests from the community to become involved. The Science Team is a mixture of representatives from government-sponsored laboratories and universities. We are striving to cultivate a rich relationship among members of these institutions, using strengths of each for the betterment of the project. For example, it is our expectation that university team members will involve graduate students and post-doctoral fellows as has been the case in past campaigns. It is also our expectation that government-sponsored laboratories involved in this study will use Education and Outreach programs within their organizations to help provide some support for the educational and training aspects of PECAN.

6. Data management plan

PECAN data will consist of observations from its field campaign, auxiliary data from operational sources, and output from numerical model simulations. PECAN proposes a data management strategy that will include: (i) utilization of questionnaires and the preparation of a Data Management Plan that defines data requirements and provides a comprehensive data management support strategy prior to the field phase; (ii) the collection of special high-resolution datasets in real-time and post field phase (e.g., GOES satellite data; NWS soundings; WSR-88D radar; ARM datasets); (iii) set-up and support of a project data management website and distributed long-term PECAN data archive; (iv) quality control and post processing of operational and research data necessary to the development of common format datasets for soundings and surface stations and; (v) the creation of radar data mosaics using common format radar data. PECAN proposes that the project website and archive be located at EOL. This centralized archive site will allow investigators to archive data and metadata at a single location or provide links to alternate archive sites.

6.1 PECAN field catalog

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

6.2 Long-term data archive

The development and maintenance of a comprehensive and accurate data archive is a critical step in meeting the science objectives of PECAN. The primary data archive will be with the NCAR/EOL. The NCAR/EOL data stewardship will ensure long-term integrity of the data. The PECAN project will request support from EOL to assist the project in the planning and implementation of a data management strategy by following the data policies, data format requirements and protocol consistent with NSF guidelines. This includes providing metadata, data and documentation as soon as possible following the end of the field phase, typically within one year. Assistance will also be requested to implement a process for PECAN data submission and archival; to provide specialized data collection and processing support and to design a distributed archive. The entire PECAN dataset will be available only for PECAN PIs for 1-year after the release of the quality-controlled dataset. Thus, only the PECAN PIs and their collaborators will have data access in the first year. After the first year, the entire dataset will be open to the general scientific community.

6.3 Special data processing tasks

PECAN is interested in the possibility of developing special compilations of data collected during the field season. This might include combining research and regional operational rawinsonde data into a quality controlled high resolution dataset for use in analysis phase case studies, modeling analysis, etc. The provision of a high quality compilation of surface station data in the region is also of interest to PECAN. This dataset would combine surface data from research (radar, mobile mesonets, etc) platforms and operational surface arrays (e.g. Oklahoma, West Texas and Kansas Mesonets, NWS ASOS stations, FAA AWOS stations, etc.) into a quality controlled common format dataset valuable for both case studies and model analysis activities. Ideally PECAN would create common format radar data, that can be used directly for perusal, editing, and analysis purposes via NCAR-supported software. These common format radar data will also be utilized for a radar mosaic, created by EOL, which would combine WSR-88D, S-PolKa, fixed ARM radars and mobile radars.

7. Education, training, and outreach

Graduate and undergraduate students from participating universities will be essential in data collection, esp. in the operation of the radiosonde units, the mobile mesonets, and the mobile radars. Student assistance will be needed in the Operations Center in the maintenance of the field catalog, the production of composite quick look images, and in forecasting/nowcasting duties. Students may have the opportunity to take on specific functions aboard aircraft such as the UWKA. The participating universities (CSU, OU, UIUC, UAH, Howard, NCSU, U Iowa, Millersville, and U Wyoming) plan to support a total of about 30 essential student positions in the field during PECAN, ~70% of them graduate students. In addition to specific assignments, all participating students will be invited to convene at the Operations Center for a student symposium dealing with both the PECAN science and the measurement techniques, with seminars given by the participating PIs.

As an outreach effort, undergraduate students from various institutions will be invited to visit PECAN operations, in particular S-PolKa, a nearby PISA unit, and all mobile radar and profiling facilities at the operations center in Hays, KS. This will be based on the week-long for-credit field excursions into the Great Plains that several undergraduate programs in atmospheric science (such as Millersville) offer during the spring/summer storm season. Participating PIs from universities such as UIUC, U Iowa and OU may bus students to Hays to visit facilities. Visits from participating and other universities can be scheduled well in advance, as they can be accommodated both during and between IOPs: students will enjoy seeing PECAN in action, and they will learn much from a tour of the facilities between IOPs.

References

Anderson, C. J., and R. W. Arritt, 1998: Mesoscale convective complexes and persistent elongated convective systems over the United States during 1992 and 1993. *Mon. Wea. Rev.*,**126**, 578–599.

Anderson, C. J., and R. W. Arritt, 2001: Representation of summertime low-level jets in the Central United States by the NCEP–NCAR Reanalysis. *J. Climate*, **14**, 234–247.

Anderson, C. J., and J. Correia, Jr., 2013: Are non-hydrostatic dynamics necessary for climate simulations of Midwest mesoscale convective systems? *J. Climate*, in review.

Arritt, R. W., T. D. Rink, M. Segal, D. P. Todey, C. A. Clark, M. J. Mitchell, and K. M. Labas, 1997: The Great Plains low-level jet during the warm season of 1993. *Mon. Wea. Rev.*, **125**, 2176–2192.

Bellamy, J. C., 1949: Objective calculations of divergence, vertical velocity, and vorticity. *Bull. Amer. Meteor. Soc.*, **30**, 45-49.

Billings, J.M., and M.D. Parker, 2012: Evolution and maintenance of the 22–23 June 2003 nocturnal convection during BAMEX. *Wea. Forecasting*, accepted.

Bonner, W.D.,1968: Climatology of the low level jet. *Mon. Wea. Rev*., **96**, 833–85.

Brandes, E. A., A. V. Ryzhkov, and D. S. Zrnić, 2001: An evaluation of radar rainfall estimates from specific differential phase. *J. Atmos. Oceanic Technol.*, **18**, 363–375.

Brandes, E. A., G. Zhang, J. Vivekanandan, 2003: An evaluation of a drop distribution–based polarimetric radar rainfall estimator. *J. Appl. Meteor.*, **42**, 652–660.

Bringi, V. N., G. Huang, V. Chandrasekar, E. Gorgucci, 2002: A methodology for estimating the parameters of a Gamma raindrop size distribution model from polarimetric radar data: application to a squall-line event from the TRMM/Brazil campaign. *J. Atmos. Oceanic Technol.*, **19**, 633–645.

Browell, E.V., S. Ismail, W.M. Hall, A.S. Moore, Jr., S.A. Kooi, V.G. Brackett, M.B. Clayton, J.D.W. Barrick, F.J. Schmidlin, N.S. Higdon, S.H Melfi, and D.N. Whiteman, 1997: “LASE validation experiment”, in *Advances in Atmospheric Remote Sensing with Lidar*, A. Ansmann, R. Neuber, P. Rairoux, and U. Wandinger, eds., Springer-Verlag, Berlin, 289-295.

Browning, K. A., J. H. Marsham, J. C. Nicol, F. M. Perry, B. A. White, A. M. Blyth, and S. D. Mobbs, 2010: Observations of dual slantwise circulations above a cool undercurrent in a mesoscale convective system. *Quart. J. Royal Meteorol. Soc*., 136: 354-373. DOI: 10.1002/qj.582.

Brunet, G., and Co-authors, 2010: Collaboration of the weather and climate communities to advance subseasonal-to-seasonal prediction. *Bull. Amer. Meteor. Soc.,* **91**, 1397-1406.

Carbone, R. E., J. D. Tuttle, D. A. Ahijevych, and S. B. Trier, 2002: Inferences of predictability associated with warm season precipitation episodes. *J. Atmos. Sci*., **59**, 2033–2056.

Clark, A. J., W. A. Gallus, and T. C. Chen, 2007: Comparison of the diurnal precipitation cycle in convection-resolving and non-convection-resolving mesoscale models. *Mon. Wea. Rev.*, **135**, 3456–3473.

Clark, A., and co-authors, 2012: An overview of the 2010 Hazardous Weather Testbed Experimental Forecast Program Spring Experiment. *Bull. Amer. Meteor. Soc*., accepted.

Coleman, T. A., and K. R. Knupp, 2011: Radiometer and profiler analysis of the effects of a bore and a solitary wave on the stability of the nocturnal boundary layer. *Mon. Wea. Rev*., **139**, 211–223.

Colman, B. R., 1990: Thunderstorms above frontal surfaces in environments without positive CAPE. Part I: A climatology. *Mon. Wea. Rev*., **118**, 1103–1122.

Dai, A., 2001: Global precipitation and thunderstorm frequencies. Part II: Diurnal variations. *J. Climate*, **14**, 1112–1128.

Davis, C. A., K. W. Manning, R. E. Carbone, S. B. Trier, and J. D. Tuttle, 2003: Coherence of warm-season continental rainfall in numerical weather prediction models. *Mon. Wea. Rev*., **131**, 2667-2679.

Davison, J. L, R. M. Rauber, and L. Di Girolamo, 2013: A revised conceptual model of the tropical marine boundary layer. Part II: Detecting relative humidity layers using Bragg scattering from S-band radar. *J. Atmos. Sci*., in review.

Drake, V.A. and Reynolds, D.R., 2012: *Radar Entomology: Observing Insect Flight and Migration*. CABI, Wallingford, UK, 496 pp. ISBN 978 1 84593 556 6.
Easterling, D. R., and P. J. Robinson, 1985: The diurnal variation of thunderstorm activity in the United States. *J. Climate Appl. Meteor*., **24**, 1048–1058.
French, J., and M. D. Parker, 2010: The response of simulated nocturnal convective systems to a developing low-level jet. *J. Atmos. Sci.*, **67**, 3384–3408.
Fritsch, J. M. and R. E. Carbone, 2004: Improving Quantitative Precipitation Forecasts in the warm season: A USWRP research and development strategy. *Bull. Amer. Meteor. Soc.*, **85**, 955–965.
Fulton, R., D. S. Zrnić, R. J. Doviak, 1990: Initiation of a solitary wave family in the demise of a nocturnal thunderstorm density current. *J. Atmos. Sci*., **47**, 319–337.
Geerts, B., and T. Dejene, 2005: Regional and diurnal variability of the vertical structure of precipitation systems in Africa based on spaceborne radar data. *J. Climate*, **18**, 893–916.
Hardesty, R. M., and R. E. Hoff, 2012: Thermodynamic Profiling Technologies Workshop Report. NCAR Tech. Note, In preparation.
Heideman, K. F., and J. M. Fritsch, 1988: Forcing mechanisms and other characteristics of significant summertime precipitation. *Wea. Forecasting*, **3**, 115–130.
Hering, W. S. and T. R. Borden, 1962: Diurnal variations in the wind field over the central United States. *J. Atmos. Sci.*, **19**, 81–86.
Hoecker, W. H., 1963: Three southerly low-level jet systems delineated by the Weather Bureau special PIBAL network of 1961. Mon. Wea. Rev. 91, 573-582.
Hoecker, W. H., 1965: Comparative physical behavior of southerly boundary-layer wind jets. Mon. Wea. Rev., 93, 133-144.
Hubbert, J. C., M. Dixon, S. M. Ellis, 2009: Weather radar ground clutter. Part II: real-time identification and filtering. *J. Atmos. Oceanic Technol.*, **26**, 1181–1197.
Jirak, I. L., and W. R. Cotton, 2007: Observational analysis of the predictability of mesoscale convective systems. *Wea. Forecasting*, **22**, 813–838.
Jorgensen, D. P., T. R. Shepherd, and A. S. Goldstein, 2000: A dual-pulse repetition frequency scheme for mitigating velocity ambiguities of the NOAA P-3 airborne Doppler radar. *J. Atmos. Oceanic Technol*., **17**, 585–594.
Johnson, R. H., 2011: Diurnal cycle of monsoon convection. The Global Monsoon System: Research and Forecast, World Scientific Series on Asia-Pacific Weather and Climate, Vol 5, World Scientific, 2nd edition, Singapore, ed. by Chang, C.-P., Ding, Y., N.-C. Lau, R.H. Johnson, B. Wang and T. Yaunari, pp. 257-276
Kincer, J. B., 1916: Daytime and nighttime precipitation and their economic significance. *Mon. Wea. Rev*., **44**, 628–633.
Kingsmill, D. E., and N. A. Crook, 2003: An observational study of atmospheric bore formation from colliding density currents. *Mon. Wea. Rev*., **131**, 2985–3002.
Knight, C. A., L. J. Miller, 1998: Early radar echoes from small, warm cumulus: Bragg and hydrometeor scattering. *J. Atmos. Sci*., **55**, 2974–2992.
Knupp, K., 2006: Observational Analysis of a Gust Front to Bore to Solitary Wave Transition within an Evolving Nocturnal Boundary Layer. *J. Atmos. Sci*., **63**, 2016–2035.
Koch, S. E., and W. L. Clark, 1999: A nonclassical cold front observed during COPS-91: frontal structure and the process of severe storm initiation. *J. Atmos. Sci.*, **56**, 2862–2890.
Koch, S.E., W. Feltz, F. Fabry, M. Pagowski, B. Geerts, D. O. Miller, and J. W. Wilson, 2008: Turbulent mixing processes in atmospheric bores and solitary waves deduced from profiling systems and numerical simulation. *Mon. Wea. Rev.*, **136**, 1373-1400.
Kropfli, R. A., 1986: Single Doppler radar measurements of turbulence profiles in the convective boundary layer. *J. Atmos. and Oceanic Technol*., 3, 305-314
Li, Y., and R. B. Smith, 2010: The detection and significance of diurnal pressure and potential vorticity anomalies east of the Rockies. *J. Atmos. Sci*., **67**, 2734–2751.

Liu, C., and M. W. Moncrieff, 2000: Simulated Density Currents in Idealized Stratified Environments. *Mon. Wea. Rev.*, **128**, 1420–1437.
Mahrt, L., 1985: Vertical structure and turbulence in the very stable boundary layer. *J. Atmos. Sci*., **42**, 2333-2349.
Marsham, J. H., S. B. Trier, T. M. Weckwerth and J. W. Wilson, 2011: Observations of elevated convection initiation leading to a surface-based squall-line during 13 June IHOP_2002, *Mon. Wea. Rev.*, **139**, 247 -271.
Martin, W. J., and A. Shapiro, 2005: Impact of radar tilt and ground clutter on wind measurements in clear air. *J. Atmos. Oceanic Technol*., **22**, 649–663.
Martin, W. J., and A. Shapiro, 2007: Discrimination of bird and insect radar echoes in clear air using high-resolution radars. *J. Atmos. Oceanic Technol*., **24**, 1215–1230.
Means, L. L., 1952: On thunderstorm forcing over the central U.S.. *Mon. Wea. Rev*., **80**, 165–189.
National Research Council, 2009: *Observing Weather and Climate from the Ground Up*. *A nationwide network of networks*. 234 pp. Available from http://www.nap.edu.
National Research Council, 2010: *When Weather Matters: Science and Services to Meet Critical Societal Needs.* The National Academies Press, Washington, DC. Available from http://www.nap.edu.
Nesbitt, S. W., and E. J. Zipser, 2003: The diurnal cycle of rainfall and convective intensity according to three years of TRMM measurements. *J. Climate*, **16**, 1456–1475
NSSP Staff, 1963: Environmental and thunderstorm structures as shown by National Severe Storms Project observations in Spring 1960 and 1961. *Mon. Wea. Rev*., **91**, 271-292.
Parker, M. D., 2008: Response of simulated squall lines to low-level cooling. *J. Atmos. Sci.*, **65**, 1323–1341.
Parsons, D.B., J. Wang, C. Pettet and K. Haghi, 2013: A climatology of bores during IHOP_2002 and implications for convection. To be submitted.
Pitchford, K. L. and J. London, 1962: The low-level jet as related to nocturnal thunderstorms over Midwest United States. *J. Appl. Meteor*., **1**, 43–47.
Pritchard, M. S., M. W. Moncrieff, and R. C. J. Somerville, 2011: Orogenic propagating precipitation systems over the United States in a global climate model with embedded explicit convection. *J. Atmos. Sci*., **68**, 1821–1840.
Spencer, P. L., D. J. Stensrud, and J. M. Fritsch, 2003: A method for improved analyses of scalars and their derivatives. *Mon. Wea. Rev*., **131**, 2555-2576.
Ryzhkov, A. V., D. S. Zrnic, J. C. Hubbert, V. N. Bringi, J. Vivekanandan, E. A. Brandes, 2002: Polarimetric Radar observations and interpretation of co-cross-polar correlation coefficients. *J. Atmos. Oceanic Technol.*, **19**, 340–354.
Sun, J., D. H. Lenschow, and Co-authors, 2002: Intermittent turbulence associated with a density current passage in the stable boundary layer. *Boundary- Layer Meteorol*., **105**, 199–219.
Sun, J., D. H. Lenschow, and Co-authors, 2004: Atmospheric disturbances that generate intermittent turbulence in nocturnal boundary layers. *Boundary- Layer Meteorol*., **110**, 255-279.
Tripoli, G. J. and W. R. Cotton, 1989a: Numerical Study of an Observed Orogenic Mesoscale Convective System. Part 1: Simulated Genesis and Comparison with Observations. *Mon. Wea. Rev.*, **117**, 273–304.
Tripoli, G. J. and W. R. Cotton, 1989b: Numerical Study of an Observed Orogenic Mesoscale Convective System. Part 1: Simulated Genesis and Comparison with Observations. *Mon. Wea. Rev.*, **117**, 273–304.
Trier, S. B., C. A. Davis, D. A. Ahijevych, M. L. Weisman, and G. H. Bryan, 2006: Mechanisms supporting long-lived episodes of propagating nocturnal convection within a 7-day WRF model simulation. *J. Atmos. Sci.*, **63**, 2437–2461.
Trier, S. B., C. A. Davis, and D. A. Ahijevych, 2010: Environmental controls on the simulated diurnal cycle of warm-season precipitation in the continental United States. *J. Atmos. Sci.*, **67,** 1066–1090.
Tuttle, J. D., and C. A. Davis, 2006: Corridors of warm season precipitation in the central United States. *Mon. Wea. Rev*., **134**, 2297–2317.

Vivekanandan, J., D. S. Zrnic, S. M. Ellis, R. Oye, A. V. Ryzhkov, and J. Straka, 1999: Cloud microphysics retrieval using S-band dual-polarization radar measurements. *Bull. Amer. Meteor. Soc.*, **80,** 381–388.

Wakimoto, R. M., and H. V. Murphey, 2010: Analysis of convergence boundaries observed during IHOP_2002. *Mon. Wea. Rev*., **138**, 2737–2760.

Wallace, J. M., 1975: Diurnal variations in precipitation and thunderstorm frequency over the conterminous United States. *Mon. Wea. Rev*., **103**, 406–419.

Wang, Z. and Co-authors, 2011: Observations of boundary layer water vapor and aerosol structures with a compact airborne Raman lidar. 5th Symposium on Lidar Atmospheric Applications, 91st AMS Annual Meeting, Seattle.

Weckwerth, T. M., and D. B. Parsons, 2006: A review of convection initiation and motivation for IHOP_2002. *Mon. Wea. Rev.*, **134**, 5–22.

Weckwerth, and co-authors, 2004: An overview of the International H_2O Project (IHOP_2002) and some preliminary highlights. *Bull. Amer. Meteor. Soc*., **85**, 253-277.

Weisman, M. L., C. Davis, W. Wang, K. W. Manning, and J. B. Klemp, 2008: Experiences with 0-36-h explicit convective forecasts with the WRF-ARW model. *Wea. Forecasting*, **23**, 407-437.

Wilson, D. A., 1970: Doppler radar studies of boundary layer wind profiles and turbulence in snow conditions. Proc. 14th Conf. on Radar Meteorology, Tuscon, Amer. Meteor. Soc., 191-196.

Wilson, J. W. and R. D. Roberts, 2006: Summary of convective storm initiation and evolution during IHOP: observational and modeling perspective. *Mon. Wea. Rev*., **134**, 23-47.

Whiteman, D. N., and Coauthors, 2006: Raman Lidar Measurements during the International H2O Project. Part II: Case Studies. *J. Atmos. Oceanic Technol.*, **23**, 170–183.

Wyngaard, J. C., 1973: *On surface-layer turbulence*, in D. D. Haugen (ed.). Workshop on Micrometeorology, Amer. Meteor. Soc., Boston, pp. 101-149.

Ziegler, C. L., 1999: Issues in forecasting Mesoscale Convective Systems: An observational and modeling perspective, Chapter 32, Vol. 2, STORMS, R. Pielke, Jr. and R. Pielke, Sr, Eds., Routledge Press, London, 26-42

Section I of SPO: PECAN Facilities Requested

NSF Lower Atmospheric Observing Facilities to be requested

item	contact PI	estimated cost*
Deployment pool funds:		
U Wyoming King Air with WCL, Raman lidar and 120 flight hours	Bart Geerts, U Wyoming	$320,000
2 NCAR ISS with 120 sondes each	Tammy Weckwerth, NCAR	$309,708
NCAR MISS with 120 sondes	Tammy Weckwerth, NCAR	$156,410
ISS-449 profiler with 120 sondes	David Parsons, U Oklahoma	$262,337
NCAR S-Pol-Ka	Tammy Weckwerth, NCAR	$421,670
DOW6, DOW7, and RSDOW	Bart Geerts, CSWR	$450,000
Special funds:		
NCAR field catalog, data management and archiving of radar mosaics	Geerts et al., U Wyoming	$400,000
FPS with Operation Center	Geerts et al., U Wyoming	$250,000

* based on budgets submitted in spring 2012, for deployment in 2014.

Requests to NSF for deployment of P/I provided facilities in PECAN

facility	deployment location	contact PI	estimated cost*
Millersville U. Integrated Atmospheric Boundary Layer Facility, plus 120 radiosondes	FP2	Richard Clark, Millersville U.	$100 K
Howard U. ALVICE Raman lidar & GLOW, microwave radiometer, and 120 radiosondes	FP2	Belay Demoz, Howard U.	$100 K
120 radiosondes	FP3	Russ Schumacher, CSU	$23 K
NPS Lower Atmosphere Profiling and Flux System (tethersonde and flux tower)	FP4	Qing Wang, Naval Postgraduate School	$70 K
OU Collaborative Lower Atmospheric Mobile Profiling System (CLAMPS), plus the U. Wisconsin mobile AERI and aerosol lidar, and 200 radiosondes	MP1 and MP3	David Turner, NSSL and U. of Oklahoma, and Wayne Feltz, U. Wisconsin	$260 K (partly funded by NSSL and OU)
U of Alabama at Huntsville Mobile Integrated Profiling System (MIPS) and the Mobile Alabama X-Band (MAX) dual-pol Radar, plus 120 radiosondes	MP2	Kevin Knupp, U. Alabama at Huntsville	$125 K
NPS-CIRPAS TWOLF, FM-CW and OU RaXPol dual-pol Radar	MP3	David Parsons, U. Oklahoma	$65 K
SMART-R C-band radars, + field travel & expendables for 2 mobile NSSL sounding vehicles	mobile	Conrad Ziegler, NSSL, and Mike Biggerstaff, U. Oklahoma	$408 K
U Wyoming compact or Tq Raman Lidar	UWKA	Bart Geerts, U Wyoming	$145 K

* based on budget estimates provided by the P/Is.

Section J of SPO: Summary of one-page community statements of interest

PI name	PI first name	affiliation	co-PIs	tentative proposal title	tentative funding source	NSF funds to be requested ($K)	priority platforms/instruments
Bell	Michael	U Hawaii Manoa		Convective and stratiform contributions to MCS longevity	NSF AGS	$420	NOAA P-3 and Doppler radar network
Cai	Huaqing	NCAR		Studying Elevated Convection Triggering Mechanisms from Nowcasting Point of View	NCAR base funds, FAA	$0	all available datasets, mainly radar and PISA data
Clark	Richard	Millersville	Scott Sikora	Characterizing the transition to and maintenance of the SBL	NSF AGS	$360	500 m tethersonde, 1 ISFS, backscatter lidar, radiosonde
Demoz	Belay	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 (deployment) NSF (analysis)	$400	NASA/GSFC Raman lidar (Alvice), wind lidar (GLOW), plus radiosondes, ceilometer, Leosphere lidar
Ferrare	Richard	NASA	Syed Ismail, John Hair	LASE Measurements during PECAN	NASA	$0	LASE, soundings
Gallus	William	ISU	Segal	Understanding the Predictability of Initiation and Morphological Evolution of PECAN nocturnal	NSF AGS	$250	all available datasets, mainly T, q, and wind data
Geerts	Bart	U Wyoming	Zhien Wang	Mesoscale Convective Systems	NSF AGS	$594	UWKA
Hanesiak	John	U Manitoba	Weckwerth	Nocturnal Boundary Layer/LLJ evolution and Elevated Convection Initiation	NSERC Canada	$0	2 MWRs, 2 Leosphere wind lidars, 1 AERI, possibly radiosonde system from EC
Jorgensen	David	NOAA	T. Schuur, C. Ziegler, Steven Koch	Microphysics and cold-pool dynamics of nocturnal MCSs	NOAA ($505K)	$0	NOAA P-3 with tail X-band dual-Doppler
Kang	Song-Lak	TTU	Huaqing Cai, Yubao Liu	A Numerical Study of Nocturnal Convection over the Great Plains with a Coupled MM-LES Framework	NSF AGS	$500	all available datasets, mainly radar and PISA data

PI name	PI first name	affiliation	co-PIs	tentative proposal title	tentative funding source	NSF funds to be requested ($K)	priority platforms/instruments
Knupp	Kevin	UAH		Kinematic and thermodynamic properties of boundaries within the Great Plains nocturnal boundary layer and their role in convective initiation and maintenance of MCSs	NSF AGS	$525	MIPS, MAX & other scanning radars, soundings, surface fluxes
Kosiba	Karen	CSWR	Josh Wurman	The transition from discrete supercell convection to MCS and Quantitative Precipitation Estimation (QPE) from dual-polarimetric radars	NSF GEO	$830	2 dual-freq dual-pol DOWS, 1 rapid-scan DOW, other pol radars, sfc mesonet, thermodynamics aloft. NOAA P-3 "useful"
Li	Yanping		Richard Carbone	Examining PV anomalies as a possible mechanism contributing to the occurrence of nocturnal	NSERC Canada	$0	PECAN Integrated Sounding Array
Marsham	John	NCAS, UK		The role of organized convection for model biases over the summertime continental USA	NERC, UK	$0	processed, gridded PECAN datasets
Mc Farquhar	Greg	UIUC	Bob Rauber, Brian Jewett	Microphysical processes within stratiform regions of deep nocturnal convective systems and their relationship to stable boundary layer dynamics	NSF AGS	$740	NOAA P-3 with tail X-band dual-Doppler, WSR-88D network
Parker	Matthew	NCSU	NSSL/OU team	Dynamics and low-level structures of convective systems in the stable nocturnal boundary layer	NSF AGS	$271	NSSL mobile soundings, other PECAN data
Parsons	David	OU	Howie Bluestein	The mechanisms for the maintenace of nocturnal convective systems	NSF AGS	$125	NPS FM-CW W-band radar and T-WOLF Doppler wind lidar, + RaXPOL
Pinto	James	NCAR	M. Steiner, J. Grim, Huaqing Cai, Mei Xu	Object-based analysis of the predictability of the macrophysical properties of nocturnal MCSs	FAA, NASA	$0	none - uses PECAN analyses provided by other PIs
Schu-macher	Russell	CSU		Low-level structures within nocturnal convective systems and their roles in determining the distribution of precipitation	NSF AGS	$333	all soundings, radars, precip gauges

PI name	PI first name	affiliation	co-PIs	tentative proposal title	tentative funding source	NSF funds to be requested ($K)	priority platforms/instruments
Shapiro	Alan	OU	Evgeni Fedorovich	Low-level jets in the nocturnal SBL: their structure, evolution and interactions with bores	NSF AGS	$540	PISA data, esp. those with high resolution near the surface
Trier	Stanley	NCAR	Chris Davis, D. A. Ahijevych	ARW-WRF Simulations of Thermodynamic Destabilization Supporting MCSs in PECAN	NCAR base funds	$0	mainly PISA data
Turner	David	NSSL	Petra Klein, Wayne Feltz, Dave Parsons	Evolution of the NBL during PECAN	NSF AGS	$685	NSSL/OU mobile Doppler lidar, MWR, AERI system
Wang	Qing	NPS		Characterizing the Role of Stable Boundary Layers in Convection Initiation and Development	NSF	$510	one tall flux tower, NPS mini-sodar, rawinsonde, and 100 m tethersonde
Wang	Xugang	CAPS/OU	Dave Parsons	High Resolution Numerical Simulations of Nocturnal Convection Bores and Other Wave-like Disturbances over the Great Plains	NSF AGS	$450	PISA data, esp. those with high resolution near the surface, and other PECAN data
Weck-werth	Tammy	NCAR	James W. Wilson, Rita D. Roberts	Studying Elevated Convection Initiation	NCAR base funds	$300	S-POL, UWKA, radars/lidars, PISAs esp. soundings
Wulf-meyer	Volker	U Hohenheim	Andreas Behrendt	Studying nocturnal, elevated convection by remote sensing of 3D temperature and water-vapor fields	DFS, EU and NSF	$0	Spol and other components of FP3, esp the ISS-449
Ziegler	Conrad	NSSL/OU	M. Biggerstaff, M. Coniglio, E. Mansell, and T. Schuur	Evolution of Initiated Convective Clusters and Mesoscale Convective Systems in the nocturnal SBL	NSF AGS and NOAA	$999	2 SMART-Rs, NSSL NO-XP, entire NSSL mobile facility, NOAA P-3