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Operations Manual: The Precipitation Augmentation for Crops Experiment (PACE)

Phase II: Exploratory Modification

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Illinois State Water Survey
Champaign, Illinois

A Division of the Illinois Department of Energy and Natural Resources

Operations Manual

THE PRECIPITATION AUGMENTATION FOR CROPS EXPERIMENT - 1989

PHASE II: EXPLORATORY MODIFICATION PHASE

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OVERVIEW OF 1989 PACE FIELD OPERATIONS

The goal of the 1989 field operations is to collect cumulus cloud data using aircraft and radars that will allow comparisons between similar clouds treated with silver iodide and those not treated with silver iodide (placebos of sand). Field operations are headquarted at Willard Airport (CMI) just south of the Champaign-Urbana campus of the University of Illinois. The study area, as shown in Fig. 1, includes all Illinois counties within a 100 mile radius of the airport. Some seeding operations will be conducted outside the study area and occasionally missions will be conducted in near by adjacent states for the purpose of collecting in-cloud data on natural clouds.

The choice of clouds to be seeded will be done randomly and on a daily basis; that is, on each operational day we will attempt to obtain seeded and non-seeded treatments of comparable clouds. Thus, the "experimental unit" encompasses clouds or rear feeder cells of an existing cloud cluster, moving, and evolving as an entity within a radius of 28 km. All possible clouds in each experimental unit will be treated one way. Clouds to be treated will be selected on the basis of visual and in-cloud criteria. The seeding aircraft will not know what type of treatment is being used to ensure blindness in the experiment.

The operation on a given day will be initiated by the type of forecast of no-go, stand-by (wait for the proper weather conditions to launch operations), or go (the launching of an operations is imminent). The forecast of go or stand-by will be for one of three cloud conditions: 1) the advent of big clouds (tops greater than 30,000 ft) in the central Illinois target area; 2) small clouds (tops lower than or equal to 30,000 ft) in the target area; and 3)

Figure 1. PACE 1989 Study Area

either big or small clouds in the area surrounding the target. (This may or may not include treatments.)

A simple view of the operations (big or small clouds) will be that the seeding/meteorological aircraft will go to 20,000 ft and choose a cloud candidate. If the candidate cloud meets certain criteria, it will be treated and an experimental unit declared. The aircraft will continue the same type of treatment (seed or placebo) of other clouds in that "group" or unit, until no more suitable clouds are evident. At that time, the aircraft will seek a second group of clouds sufficiently distant from the first group and initiate tests of a candidate and initiate treatment if the criteria are met. If a third and fourth unit of clouds develops, further selections and treatments will be applied.

Radar operations will involve the CHILL and the HOT radars. 3asically, the HOT will be used as a surveillance radar to collect reflectivity data out to 140 km to provide a presentation of all echoes. The operational van of the CHILL radar will serve as the operational control headquarters. The CHILL radar will be used for monitoring in-cloud cores using a combined 360° low level scanning mode with sector scanning of all treated echo groups, and during special operations (described below) perform sector scanning of treated echoes.

The only diversion from the above described operations will occur in May when the T-28 meteorological aircraft is present. When "big" clouds are available in the target area in May, the T-28 will either be used solo to monitor in-cloud evolution at around -10°C level or will fly with the seeding aircraft in studies of in-cloud reaction to AgI seeding. After 30 to 40 minutes (or until the cell is not distinguishable, too strong, or dissipates), the T-28 will join the seeding aircraft for a second mission if aircraft time is adequate. During these special T-28 type missions, the CHILL, radar will sector scan the echo volume that is being treated and penetrated by the T-28 aircraft.

Most operations will be concentrated within 100 miles of Champaign (the study area shown in Fig. 1). Seeding operations will be stopped if severe weather conditions develop. Operations will normally be conducted (following a morning briefing) between 1200 and 2100. Forecasts will be issued to detect cases of early morning operations. If this looks promising, a forecast for operations to begin on or after 0630 will be issued by 1700 on the prior day. The project will involve in-depth debriefings of all personnel and data after each major operation. When possible all data being collected will be processed for quality control and to initiate analyses.

The primary project personnel will include the following:

1. Stan Changnon, Project Director
2. Bob Czys, Operational Coordinator/Aircraft Meteorologist
3. Nancy Westcott, Radar Operational Director
4. Robert Scott, Chief Forecaster
5. Floyd Huff, Seeding Officer
6. Eugene Mueller, CHILL Radar Operations
7. Jerry Nespor, HOT Radar Operations
8. Norm Ostrander, Chief Pilot Seeding/Meteorological Aircraft
9. Dennis Musil, Operational Director T-28 Aircraft

INTRODUCTION

1. Background

The Precipitation Augmentation for Crops Experiment (PACE) is a research program to determine if a socially and environmentally suitable precipitation modification technology can be developed to aid agriculture and improve water resources in Illinois and the Midwest.

During the 1970's and early 1980's Illinois farmers and agribusiness employed cloud seeders to conduct 8 different summer seeding projects in parts of central and southern Illinois for the purpose of increasing rainfall to increase crop yields. However, great uncertainty over the technology as to how to perform weather modification existed, as well as the outcomes of such efforts, even though research has indicated that certain clouds are susceptible to modification in ways that may lead to more rain. Furthermore, PACE agricultural studies have shown that additional water, at critical times during the summer, will result in increased yields in approximately 8 out of 10 years. Thus, the development of a precipitation modification technology became a key water-related goal for Illinois.

The 1989 field effort and ensuing analysis have been guided by what was learned from the 1986 field experience, and these activities are being conducted within the context of overall PACE goals and objectives which were set forth in the original 1978 PACE plan. This plan stated that the goals of PACE to be:

1) to determine the precipitation alterations attainable in various growing season weather conditions;

2) to determine the impacts on all facets of agriculture due to rain alterations that could be established, and;

3) to discern the ultimate socio-economic and environmental desirability of the weather alterations.

The specific objectives of PACE as stated in 1978 were:

1) to execute carefully designed field experiments involving cloud modification and rain enhancement in the central agricultural regions of the United States;

2) to document the alteration of cloud dynamics and other physical responses from modification;

3) to develop the conceptual and numerical models to guide the experimentation in the ultimate transfer of the technology if developed;

4) to identify changes in area precipitation brought about by modification of warm season precipitation elements, and;

5) to determine any extra area effects of modification treatments.

The setting of specific goals and objectives for the Experimental Modification phase of PACE is a reflection of another aspect of PACE, the planned sequence of events. The 1978 PACE planning document indicated that PACE was potentially to be composed of 4 phases: the Pre-Experimental Phase, the Experimental Phase, a Confirmatory Phase, and a Final Analysis and Summary Phase. An important aspect of these phases was that moving forward from Phase 1 to Phase 2, for example, required a stop/go decision based on the integration of results and indications that a successful outcome could be attained.

There are two aspects of Phase 2 that are also important. Phase 2 is to be composed of Part A and Part B; with Part A devoted to exploratory cloud seeding and Part B being a more confirmatory type of experiment. Moving from the exploratory to the confirmatory experiment hinges on successful findings in the exploratory effort.

The Pre-Experimental Phase conducted during 1978 to 1984 sought to determine the potential for cloud seeding in Illinois and the Midwest, and the results did indicate that certain types of clouds may be suitable to produce more rain if the natural processes involving the freezing of supercooled water could be modified. A hypothesis for cloud and rainfall modification was developed around the concept of "dynamic seeding" and a primary aim of Part A of the Exploratory Phase of PACE is to test certain parts of the steps of this hypothesis.

2. The Dynamic Seeding Hypothesis

The Exploratory Modification Phase and the 1989 field project is being conducted to test certain parts of the Dynamic Seeding Hypothesis. Therefore, it is important for those involved with PACE to be aware of the current hypothesis as it has been formulated to apply to Illinois clouds.

The dynamic seeding hypothesis is based upon the fact that sensible heat is released in the conversion of supercooled water to ice. Since the natural conversion appears to be somewhat inefficient and considering that if natural conversion can be forced in a timely way by the introduction of silver iodide in a growing cumulus congestus cloud at about 20,000 ft (≈ -10°C level), heat release should make a cloud warm and thus more buoyant than it would be otherwise. Clouds which are made to be more buoyant should grow bigger, or last longer, or both, and thus may process more of the available water vapor and produce more rain.

The specific sequence of events in dynamic seeding presently thought to follow massive seeding are:

1) A rapid conversion of water condensate to nearly total ice particles will occur soon after seeding;

2) There will be an increase in temperature and net buoyancy throughout the region of freezing by release of latent heat;

3) The effect of buoyancy enhancement on the updraft may range from reducing net deceleration of the updraft in most cases to causing updraft acceleration in some cases, depending on the kinematic and microphysical conditions at the time of seeding.

4) In the absence of a strong elevated inversion or deep layer of dry air, cloud top will reach higher levels than it would naturally;

5) Buoyancy enhancement will somehow be communicated through the entire cloud depth resulting in an increase in moisture convergence below cloud base;

6) Overall vertical motions, including falling air, will strengthen to produce increased downdraft air which may provide a boost to the development of a subsequent cloud;

7) The horizontal extent of the active cloud will increase with a proportional increase in updraft diameter;

8) Clouds of larger size, prolonged life, or both will result in an increase in rain productivity because precipitation mechanisms operate over larger volumes, for longer times or both; total surface rainfall will increase, even though net precipitation efficiency may remain appreciably unchanged, and;

9) Rain intensity (rain/time/area) may not change appreciably but average rainfall (rain/total duration of rain) will increase from increased duration, areal coverage or both.

OBJECTIVES OF THE 1989 PACE ATMOSPHERIC FIELD PROGRAM

The data emanating from the 1989 field program involving measurements and treatments of clouds will be used to perform six interrelated studies. They are described in the following text.

1. Echo Core Behavior Studies

Studies involving the use of radar data collected during the 1989 PACE field program will center on examining the response of echoes cores to treatment, and for the response of the cloud system as a whole to treatment. Interpretation of radar data will draw on the in-cloud data for information about cloud conditions at the time of treatment and will utilize results from covariate analysis to explore for a means to normalize the cloud responses based on estimates of larger scale forcing and convective triggering mechanisms. The two main objectives of the cloud/echo behavior studies are:

1) To determine if seeded cells (convective entities), defined in an objective manner (as in the 1986 sampling), are altered (heights, areas, duration, reflectivities) in comparison to non-seeded clouds, and;

2) To discern if seeded entities (assuming they produce larger clouds) stimulate interactions between adjacent clouds.

Specific objectives of the cloud/echo behavior analysis are:

1) to investigate for seeding effects over the possible range of echo core responses to seeding based on clouds grouped according to their initial echo characteristics (heights, diameters) and behavior;

2) to investigate for seeding effects on echo cores based on clouds grouped according to . their microphysical and kinematic condition at the time of seeding;

3) to investigate for echo core responses to seeding in analysis based on grouping by the meteorological conditions representative of the rain period, and;

4) to explore the use of radar measurements in estimating the potential effect of seeding on overall cloud circulation.

In many past weather modification research projects, the detection of seeding effects has focused on study of the area wide behavior of cloud echoes. As a result of PACE exploratory research, it is believed that this traditional approach may not be appropriate for cloud systems in Midwest. The reasons for this are:

1) cloud systems often rapidly move through the target area (within radar range) so that it is not always possible to follow the complete system history;

2) it is possible to treat only a small fraction of any given population of clouds due to logistical limitations so that the natural variance of the untreated portion of the system may mask the seeding effect, and;

3) because cloud/echo responses are strongly influenced by the large scale meteorological setting, the data must be stratified according to the characteristics of the daily weather and having to do so drastically increases the number of storms that have to be sampled to achieve statistically significant results.

Thus, the analysis of the 1989 data will begin by using a "single cloud" approach to detecting dynamic seeding effects by radar, within the framework of the "multicellular" nature of the rain producing clouds. An important finding using PACE86 radar data, was that each of the 19 treated clouds could be associated with an individual echo core, at or near the time that treatment was delivered. Eighteen of the nineteen treated cores also were found to merge with an adjacent echo core at some time in their observed life cycle. Further it was found that echo core was usually distinctive enough to allow tracking in time and height from core inception, through growth stage, to at least a time when maximum echo top height, area and reflectivity first are reached. However, the echo core tracking analysis will not extend to rainfall production because as the cores become involved with the other echo cores in the system. Rainfall is the product not simply of a core (which can not always be discerned during the mature stage of a cloud), but of the multicelled system as a whole.

2. Echo Area Studies

The HOT radar will be operated to obtain low level echo reflectivity data out to 140 km and near cloud base (5,000 to 7,000 ft MSL). These data will be used to reconstruct, where and when possible, the envelopes of each treated cell and convective entities (cluster of cells). The objectives of this research are:

1) To begin to collect information on the length, width and areal dimensions of cores and convective entities that are treated;

2) To discern the analytical problems associated with such analysis, and;

3) To develop analytical techniques for future studies.

3. Mixed Phase Precipitation Process Studies

A primary objective in the collection 1989 data on in-cloud properties is to improve understanding of in-cloud reaction to treatment (Agl or placebo) while continuing to build a statistically meaningful database on the mixed phased properties, mostly around and above the -10°C level of natural clouds. A limited amount of data from slightly warmer and colder levels should also be available for analysis. In-cloud data will also be used for in-depth investigation of ice initiation/multiplication processes, in natural and treated clouds as a requisite for developing and refining a comprehensive glaciating model.

The cloud physics studies utilizing 1986 data were successful in illuminating initial microphysical properties at -10°C. Information on the microphysical evolution of natural clouds was restricted by rapid cloud development to levels beyond aircraft capabilities. Also, the number of treated clouds for which microphysical data is available is small. Therefore, the objectives of cloud physics research in the 1989 field program and subsequent analysis are designed to fill in gaps remaining from previous years. It was also designed to broaden our knowledge of the glaciation processes at later cloud stages and to focus on discerning changes in cloud properties from seeding, focusing on the relation of these changes on precipitation process. In-cloud data will also be integrated with radar data to explore a new technique for seeding effect evaluation.

Six specific research objectives have been set for the mixed phase precipitation processes studies:

1) to continue microphysical studies of natural clouds at -10°C during initial and subsequent stages of development;

2) to assess in-cloud microphysical, kinematic and thermodynamic reactions to seeding by monitoring the conversion of water-to-ice under natural and treated conditions; emphasizing the effect of altered precipitation mechanisms on productivity of rain;

3) to initiate study of the in- and out-of-cloud conditions associated with communication of seeding effects throughout the cloud volume to sub-cloud regions to identify situations which may produce cloud top "cut-off" naturally or when seeded;

4) to provide air truth for radar studies, particularly those using differential reflectivity measurement for exploratory investigation of water-to-ice conversion;

5) to provide initial conditions for computation of potential seeding response in a seeding effect evaluation using radar detected cloud responses, and;

6) to investigate the phenomena of aircraft produced ice particles as a potential source of uncertainty in the analysis.

4. Forecasting/Nowcasting Studies

The primary goal of the forecasting experiment of Phase II of PACE is to develop an objective procedure to reliably predict conditions, both of the air mass and in-cloud, which are favorable for dynamic seeding. The forecast must include a prediction of (1) the occurrence (time, location, and intensity) of convection, (2) the suitability of the environmental air mass for a dynamic response to seeding, (3) the suitability of the in-cloud conditions, notably about the supercooled water content, for dynamic seeding to be effective, and (4) relationship between thermodynamic properties and triggering mechanisms. To reach this goal several forecasting experiments have been designed for the PACE89 field operations, the results of which will need to be analyzed in the proposed research.

In PACE86, the primary objective of the forecasting unit was to provide the field operational team with a Go/No-Go forecast: the expectation of convective precipitation to occur in the target area within the operational daily period. The prediction was based solely on subjective analysis of the data via the forecasting/nowcasting system to be described. Several stability indices provided additional guidance. Hence, a subjectively based forecasting operation provided a means to develop objective procedures for the PACE89 field program.

There are two other nowcasting/forecasting studies (1) an investigation of the use of indices to forecast convection and convective intensities and (2) use of thermodynamic state variables to forecast in-cloud conditions for seeding.

The indices studies will identify single or combinations of stability indices which will reliably predict the occurrence and perhaps the intensity of convection in the target area. The thermodynamic state studies will focus on whether the potential buoyancy (PB) and the temperature of the convective condensation level (CCL_T), as derived from the morning sounding, can be used in combination a) to distinguish between Go, Stand By, and No Go Days, and b) to anticipate the seedability (i.e., effectiveness of coalescence processes to produce supercooled water to freeze by seeding). It appears from PACE forecasting studies that a good relationship exists between potential buoyancy (the arithmetic difference between the 500 mb environmental temperature and that of an air parcel raised moist adiabatically from the temperature at the CCL), cloud base temperature (temperature at the CCL) and the maximum echo top occurring in the target area.

Figure 2a shows six categories of maximum echo core heights determined from summer (June, July and August) 1986-87 NWS radar summary data plotted in the potential buoyancy- CCL_T domain. Potential buoyancy and CCL_T were determined for each day from the Salem IL, and Peoria, IL soundings. A zero indicates no echo formed during the day, a 1 indicates echoes but with maximum tops less than 20 k ft., 2 indicates maximum tops of 20 to 29 k ft, 3 indicates echoes 30 to 39 k ft, 4 40 to 49 k ft. and 5 indicates that the maximum echo tops for the day exceeded 50 k ft. The domain has been subjectively divided into area of "Go", Stand By and No Go. The type either A or B indicated a distinction between days which should have strong or weak coalescence processes. Thus, potential buoyancy (PB) and CCL_T, derived from the morning sounding will be used in PACE89 to test their effectiveness in: (1) distinguishing between Go/No-Go and Stand-By days, (2) providing a quantitative

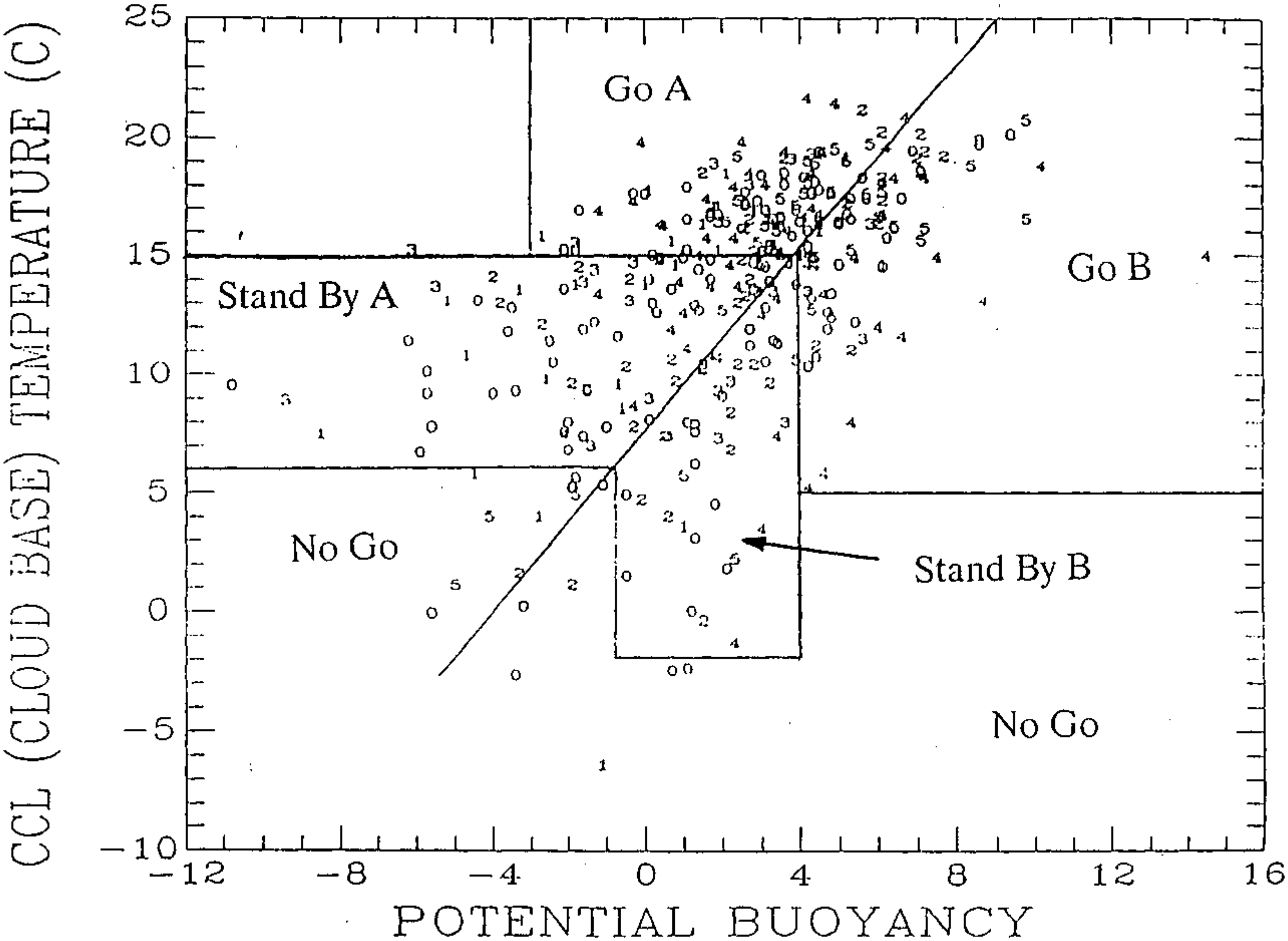


Figure 2a. Objective Forecast: Criteria

estimate of the coalescence efficiency (i.e., production of large supercooled drops at -10°C if convective clouds develop).

Figures 2b-2f in the appendix show the contours of frequency of occurrence of ranges (as indicated in the bottom right corner of each figure) of maximum echo height for combinations of potential buoyancy and CCL_T. The performance of this estimator will also be evaluated in this research. These figures will be used in a test of their utility in providing a probability distribution of the occurrence of no, small, medium and large maximum echoes. Another part of the forecasting research will be to explore the possibility of using PB and CCL_T to estimate target area rainfall.

Type A and B days have been determined using a relationship originally discussed by Mather et al. (1986). This empirical relationship is:

$$L = 8.6 - CCL_T + 1.7 \times PB$$

where L is termed the coalescence efficiency discriminator and appears as the diagonal line in Fig. 2a. When L is negative (to the left of the diagonal), the production of large drops is expected. It is believed that this relationship applies to Illinois clouds because the distribution of cloud base temperatures for Illinois clouds and those in South Africa are nearly identical. Furthermore, cloud physics data from three days during PACE86 revealed that the more negative L becomes, the more abundant and larger the size of supercooled water drops that were observed. The three objectives of the Forecasting/Nowcasting Studies:

1) To evaluate the objective forecasting procedures both old and new;

2) To identify single indexes or combinations of stability indices that reliably predict the occurrence and/or intensity of convection in the target and non target (surrounding) area, and;

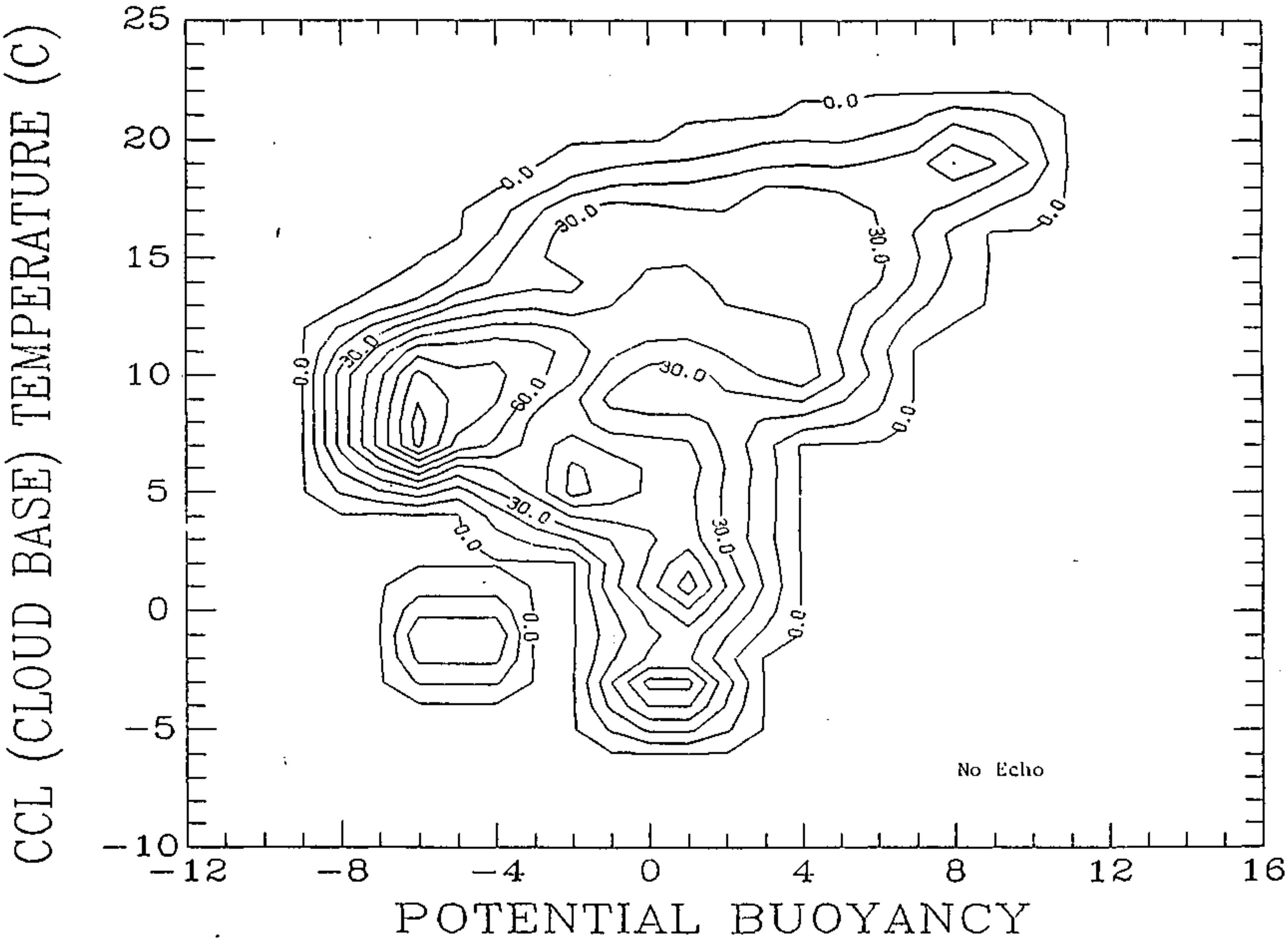


Figure 2b. Frequency of Occurrence: No Echos

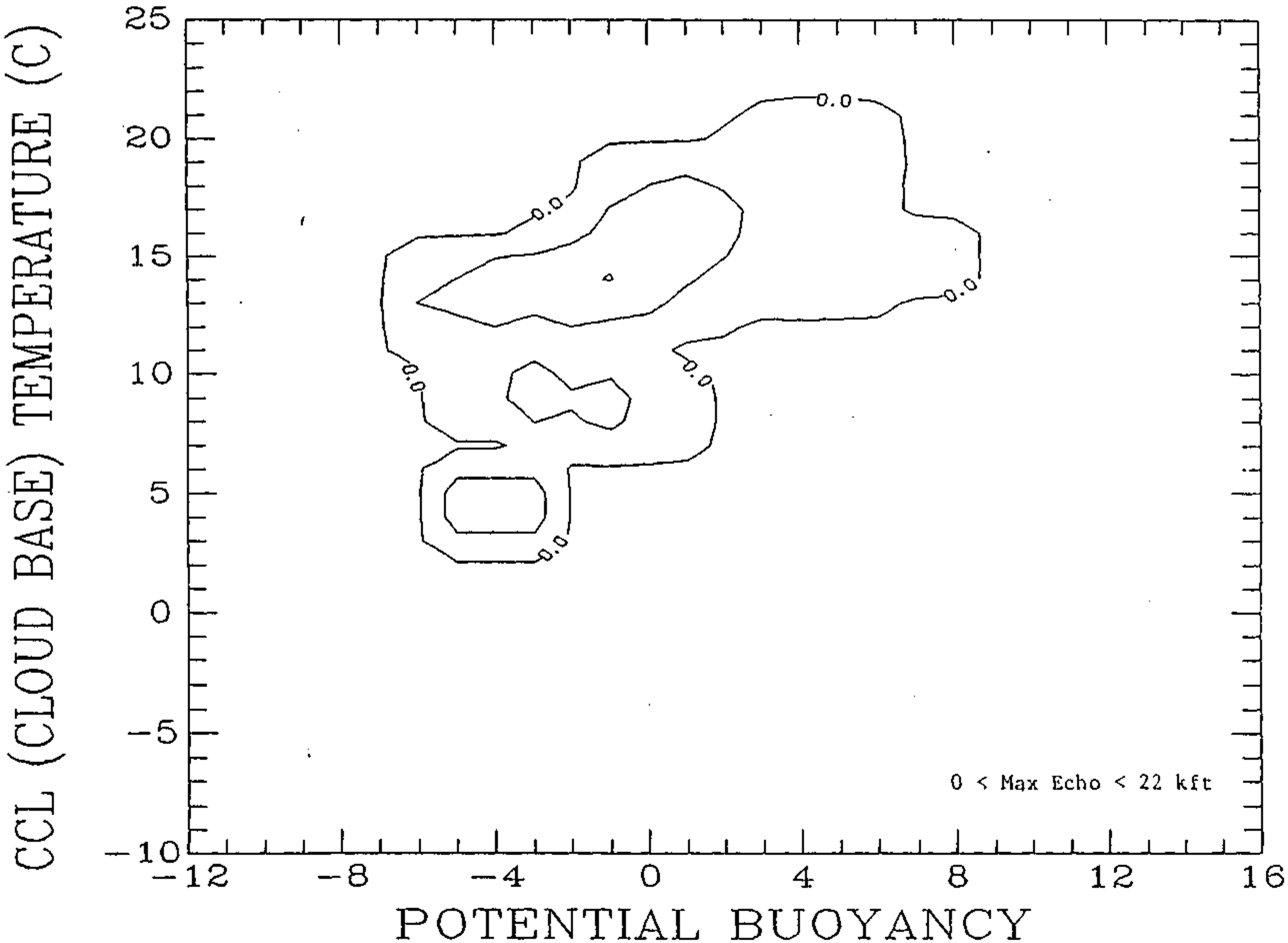


Figure 2c. Frequency of Occurrence Echos: < 22 kft

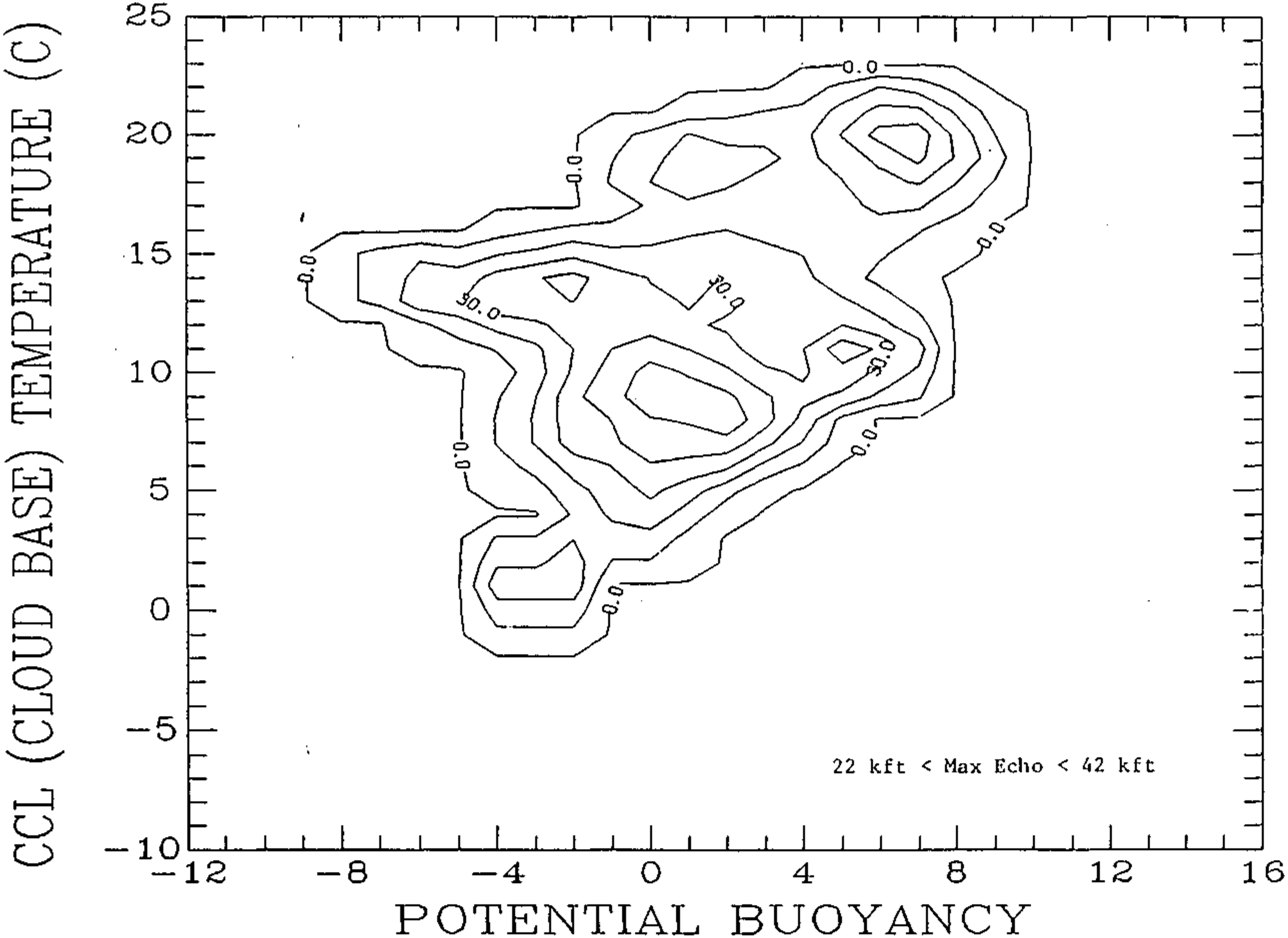


Figure 2d. Frequency of Occurrence Echos: 22 < Ell < 42 kft

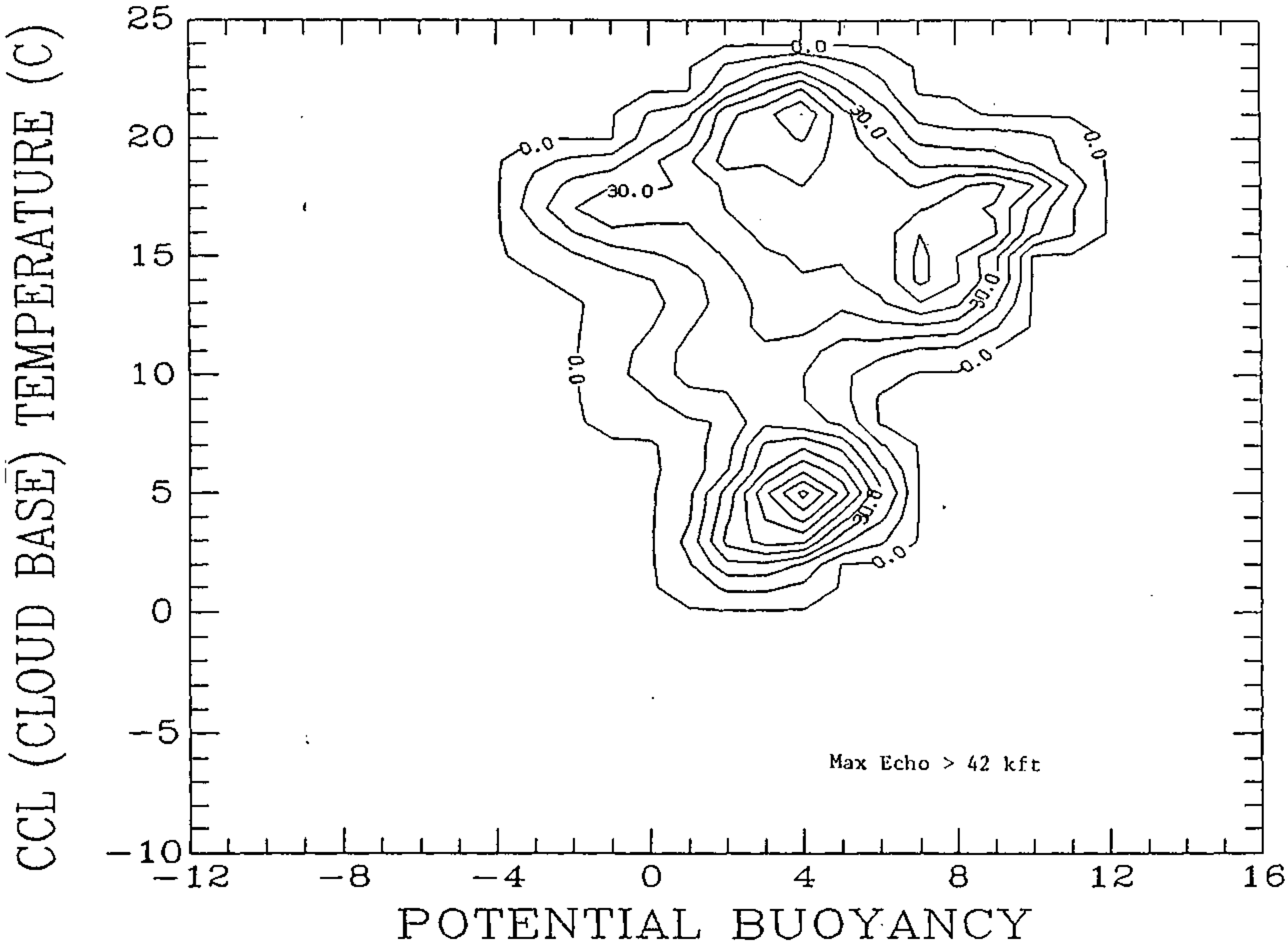


Figure 2e. Frequency of Occurrence Echos: > 42 kft

3) To determine if the moving potential buoyancy and CCL temperature can be combined a) to define the operational decisions (go, no go, stand by), or b) to anticipate the seedability.

5. Study of the Potential for Dynamic Seeding Effects

PA £86 analysis of Potential Buoyancy Enhancement (PBE), using a method described by Orville and Hubbard (1973) in which freezing is assumed to occur instantaneously and isobarically, suggested that only a fraction of the total number of clouds that receive real treatment may have buoyancy responses large enough to be of any consequence to echo core development, and thus, be seen as a response in the radar data. PACE86 data showed that many updrafts had calculated PBE's which were so small in comparison to the initial state of buoyancy (either negative, neutral or very positive) that any realistic dynamic enhancement may not be noticeable in the radar data. However, a few updrafts typically having close to neutral initial (observed) buoyancy also had calculated potential buoyancy enhancements large enough to suggest that some clouds should respond very positively to dynamic seeding, and we have assumed that these may produce evidence for a seeding effect which is more easily discernable in the radar data.

The objective of this study is: to further develop a scheme which uses information derived from the aircraft data collected at seeding levels to objectively create a subset of radar data representing clouds which are expected to show the largest dynamic response, if they had truly received the active seeding agent.

The procedure of analysis is as follows:

1) estimates of net cloud buoyancy at the time of treatment and computation of potential buoyancy enhancement due to imposed instantaneous, isobaric freezing will be made (for these estimates to be

comparable it is important that each seeding penetration be conducted at nearly the same time of cloud evolution or amount of cloud top above penetration level);

2) a window is applied to the data to remove from the data set clouds which are very positively (> 1.5 °C) and very negatively buoyant (< 1.5°C) and to remove from the list clouds whose calculated potential buoyancy enhancement is small (< 0.1°C). This procedure is followed to create a list of clouds with minimal amount of natural variability in parameters relevant to dynamic seeding. Clouds in this sub data set should have about the same initial buoyancy at seeding and about the same expected minimum response to seeding;

3) once analysis of echo core behavior is complete and the list of clouds created in step (2) is completed, the clouds will be ranked in ascending order of decay in echo core growth rate (using radar data) and the treatment type of each must be revealed;

4) clouds that tend to have the largest decay in core growth are probably not seeded, and;

5) clouds that tend to have the smallest decay in echo core growth rate are probably seeded.

6) Finally, a Sign or Wilcoxon Type Statistical Test on this response variable should show the population of the seed and no seed clouds to be statistically different.

6. ZDR and Lightning Studies

Several new facilities will be available for inclusion in the PACE analysis. ZDR data will be collected by the ISWS/NSF CHILL radar. The objective of the ZDR study are to determine if and when large drops can be observed above the 0°C isotherm, and then to determine whether the glaciation of these large drops can be detected. The meteorological/seeder aircraft and the T-28 will provide "air truth" to help interpret these measurements.

A second new resource is cloud-to-ground (C-G) lightning data from the SUNYA Lightning Detection Network which has just expanded into this area. Data obtained from the SUNYA 1989 archives will be obtained after the field program. The objective of this study is to determine whether C-G strokes are initiated earlier in seeded clouds. This would be expected if clouds are made to glaciate earlier as a result of seeding. The T-28 will carry electric field mills and thus it may also be possible to make inferences regarding intra-cloud lightning.

EXPERIMENT DESIGN

1. The Experimental Unit

The unit of experimentation is a cloud or a group of clouds, that will be treated and analyzed as a single entity. The type of treatment applied to any unit will be selected randomly by pairs.

The purpose of the experimental unit chosen for PACE89 was to select the smallest possible coherent convective entities acting individually or in unison to mesoscale dynamic forcing. Hopefully, it represents an entity with a closed circulation associated with cloud formation. Therefore, the "seedable" convective entities (cores) within the experimental unit have at least some chance of displaying similarity as the result of their in-cloud process, and thus similarity in the manifestation of these processes as measured by radar. The experimental unit, with its cloud selection and seedability criteria (defined later in this section), allows comparison of the behavior of seeded and not seeded echo cores. All cores developing within the experimental unit will receive the same treatment.

During an operation, and assuming that clouds within a potential experiment unit meet the visual criteria for selection and then the test cloud meets in-cloud criteria for seeding, the first experimental unit of the day is defined at the time that the first cloud of the day is treated (AgI or placebo). Figure 3 illustrates the components of the experimental unit as generated from the following rules and definitions:

1) The center of the unit is the first treated echo core. It is defined as the point on the radar screen illuminated nearest to the time of seeding by the RATS. The initial point of seeding will be established from aircraft information given to mission control that seeding material

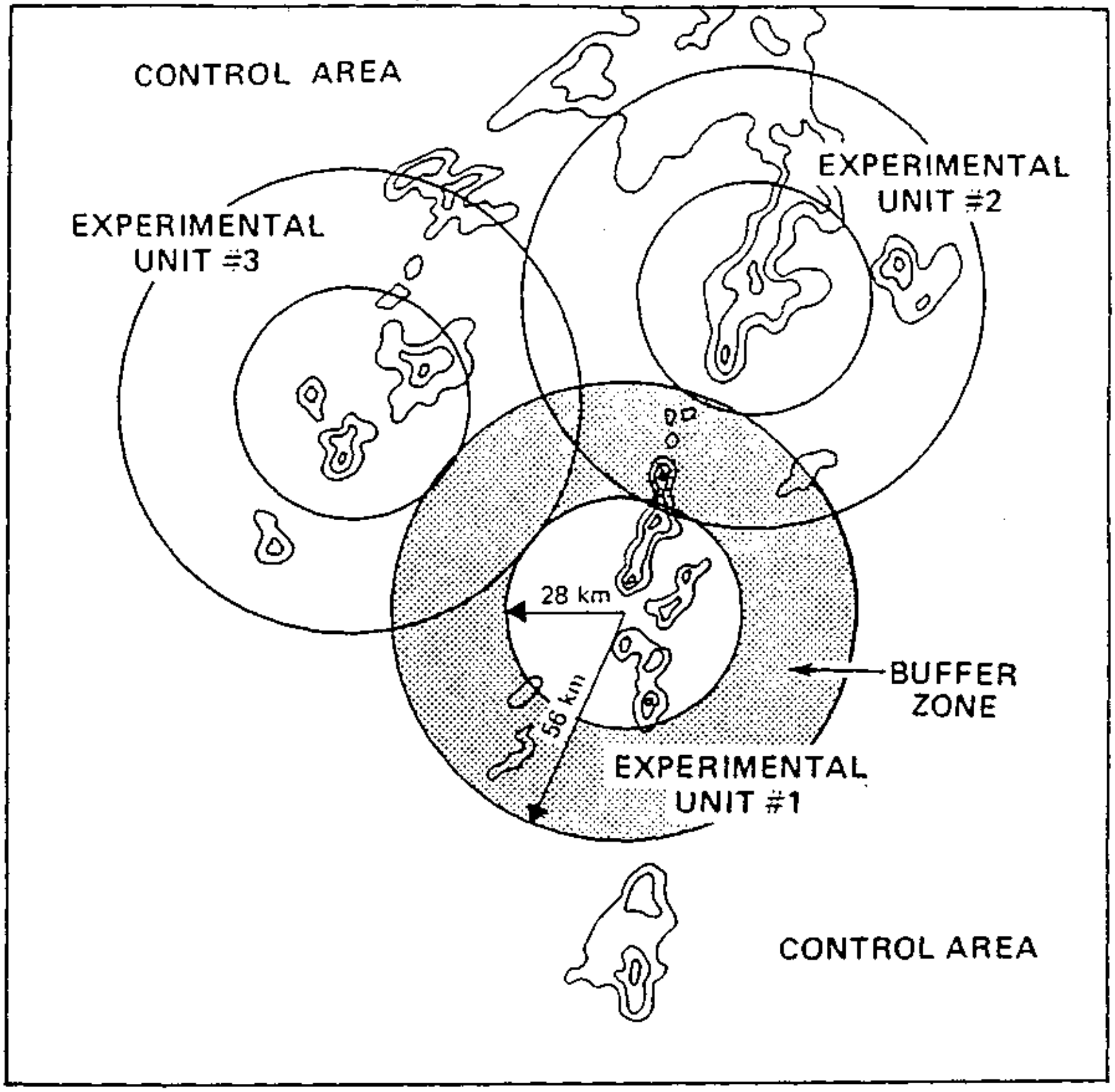


Figure 3. Example of three Experimental Units
at a given time

is about to be delivered. To further facilitate the fixing of the center point of the experimental unit, the aircraft position, time of seeding, and number of flares ejected will be conveyed back to mission control shortly after seeding.

2) The area of the experimental unit will be a circle, 28 km (15 n. mi.) in radius with center fixed by following procedures defined in 1). If one or more adjacent clouds are treated, and providing that the location of the first seeded cloud remains well within the circle, the center of the circle will be the mean of the first two treated cells.

3) Initially, the area of the experimental unit will move at the translation speed of the first treated echo core (cell motion as opposed to storm motion).

4) As the operation continues, the echo core upon which the experimental unit was established may lose its identity. In this event, the circular area of the experimental unit will be translated at the mean motion of echo cores in the vicinity of where the initial echo core lost its unique identity.

5) The experimental unit shall retain its identity, and radar observations of it shall continue until a) the clouds within it completely dissipate or b) the units move beyond radar range.

6) The area of the experimental unit will be surrounded by an annular area 28 km wide (15 n. mi.) as shown in Fig. 3. This area is called the "buffer zone".

7) No clouds occurring within the buffer zone will be selected as a second experimental unit nor treated. There is no intended use of these echo data in the analysis.

8) The definition of subsequent experimental units during a flight or day shall not include the area of any buffer zone.

9) Old and new buffer zones can overlap.

10) A "control area" (i.e., any area which is not an EU or Buffer Zone) for each experimental unit shall be defined as illustrated in Fig. 3 and echo core behavior in this area will represent the "natural" behavior of the day.

11) The aircraft will leave the experimental unit and search for a new experimental unit if a) cloud development no longer meets the selection criteria by which the randomization table was selected, b) the flare supply for that experimental unit is exhausted, or c) the development of the only echo cores suitable for seeding moves across the boundary of the circular experimental unit into the buffer zone.

12) The radar meteorologist shall use judgement as to whether the shape of the circular experimental unit can be deformed to accommodate the

treatment of echo cores that are crossing the experimental unit boundary so long as it appears that the echo cores are part of the same mesoscale convective unit (i.e., domain of the smallest closed mesoscale circulation for which a complete motion can be assumed).

During the course of a flight it is desirable and necessary, to at least select a second (or possibly a third experimental unit) in order to obtain a data set of treatments paired by mission. The procedure for defining additional experimental units during a flight is the same as described above except that 1) no new experimental unit can be composed of a previous unit, and 2) no new experimental unit can be defined downwind of a previous experimental unit. Subsequent experimental units will have a minimum separation from each previous experimental unit which is the sum of the radius used to define the size of the experiment unit and buffer zone during the flight (as shown in Fig. 3).

2. Cloud Forecasting

On a daily basis, the PACE forecaster will provide a subjective forecast of the probability of "suitable" convection in the PACE "target area" as defined in Figure 1. Suitable convection refers to convective cloud systems that include one or more convective cloud entities or feeder cells growing through the 20,000 ft level. This means that echo tops of the main cloud system will be at least 30,000 ft. These are days on which the cloud system(s) within the target area will likely produce rain. These are days which are referred to as "big" cloud days. The project forecaster will issue a Go, Standby, or No-Go declaration for "big" cloud days.

When a Go declaration is made, the development of "big" clouds is forecasted to be imminent and project personnel will ready for a mission and remain at headquarters for a mission declaration by the Operations Coordinator of the day. A Stand By declaration indicates that conditions are favorable, but the weather situation needs close monitoring before a mission declaration. When a No Go declaration is made, project personnel shall tend to the system maintenance, analysis, and archiving. Personnel are free to leave project headquarters so long as the instrumentation for which they are responsible is in a state of readiness for possible operations on the following day.

The forecaster will additionally provide subjective forecasts as to:

1) the likelihood of "small" convective cloud development within the target area, and;

2) no clouds in the target area.

Final components of the subject forecast is for extra-target area convection and this includes an assessment of the risk involved in missing in-target area clouds if convective clouds are to be sampled in the extra-target area. A Go or Stand By condition shall be declared for "small" cloud days with the same implications as that for "big" cloud days.

The forecaster will additionally provide a subjective outlook of the probability of convection in-the target on the morning and afternoon of the next day. If the outlook calls for a possibility of morning time convection, then PACE project personnel will be prepared to conduct a morning mission presumably before that morning's weather briefing. This possibility will be defined by 1700.

3. Cloud Selection and Seedability Criteria

One purpose of the cloud selection criteria is to verify the kind of convective day forecasted for, either "big" or "small" cloud day, and thus, determine the randomization schedule to be used for the experimental unit(s). Two randomization schedules have been generated, one for use on days when "big" clouds form within the range of the radar and one for use on all other days when the experiment involves cloud treatment. Another purpose of the cloud selection criteria is to assist the subgrouping of the data by days on which the clouds had similar features.

a. Criteria for "Big" Cloud Days. Initially, when viewed from the aircraft, a flight shall be categorized as a "big" cloud flight if the clouds within a potential experimental unit have a visual appearance of:

1) cumulus congestus type clouds growing as individual units or as feeder cells in the new growth region of a main cloud mass, and if they show a;

2) vertical propagation of cloud top to heights easily through -10°C, with tops surpassing an estimated 25,000 ft;

3) an outward appearance that is hard and blocky, like that of a cauliflower;

4) a minimum diameter of approximately 1 km; and

5) little or no vertical tilt.

The first aircraft penetration of the day will be used to assess the seedability of in-cloud properties. All first penetrations will be made with approximately 500 to 2000 ft of cloud above the initial level of penetration. All clouds within the experimental unit shall be called "seedable", and seeding shall occur if indications by in-cloud measurement in the initial cloud penetration are:

1) the test cloud is composed mostly of updraft;

2) the strength of at least one of the updrafts as indicated by the aircraft vertical velocity indicator reaches at least 200 ft per minute;

3) the test cloud is composed mostly of supercooled water with hot-wire measurement of at least 0.1 g m^{-3} and at least a short period of light icing on the windshield;

4) little or no ice particles, as indicated by audible ticking as ice hits the aircraft structure, and;

5) clouds do not have to possess large amounts of supercooled rain drops on the test pass, but at least a brief period of 1 mm splashing on the forward windshield is desired.

Assuming that the test cloud meets these criteria, mission control shall be informed that this is a Type I Mission and the randomization schedule will be set to A (see part 4 of this section) . The first cloud shall then be treated, and the first experimental unit of flight shall thus be defined.

b. Criteria for Randomization: Schedule B. There are three other types of missions in which treatment will be delivered to cloud: (1) Baron only missions of Type II (small clouds in the target area), (2) Baron only missions of Type III (small or big clouds in Illinois), and (3) joint T-28 and Baron missions of Type V. The criteria for each type of mission is as follows:

1) *Baron Only Missions of Type II.* In these missions, it is assumed that convective clouds are forming in the target area and that their tops are not passing through the -10°C level (approximately 20,000 ft). These clouds must also show a hard, blocky exterior; like that of a cauliflower and also little if any vertical slant. An initial test penetration of these clouds should indicate that, 1) very little ice is present and 2) that cloud droplet liquid waters are at least 0.1 g m-3. Treatment shall be delivered at ≈ -7°C. Randomization will be from schedule B. Repenetration of treated clouds at a higher altitude if possible is desired.

2) *Baron Only Missions of Type III.* These are missions, outside of the target area, but within Illinois and days which can produce either "big" or "small" clouds. In the event that big clouds are forming the selection criteria is the same as that for Type I missions. In the event that "small" clouds are forming then the criteria for selection and seedability is the same as that for missions of Type II. Randomization schedule B will remain in effect.

3) *Baron and T-28 missions of Type V.* One purpose of the T-28 is to provide data on in-cloud characteristics during the later and therefore, more intense period of echo core lifetime. This presupposes a "big" cloud day. On these days the Baron will be used to make a pre-T-28 penetration and deliver seeding material according to Randomization schedule B; requiring only that the visual criteria of Type I be met. However, a test cloud need not be found as in Type I procedures.

4. Randomization

The randomization scheme for 1989 has been formulated: (1) to maximize the number of treated (either silver iodide or placebo) clouds, (2) to achieve a relative balance between the number of clouds treated with silver iodide and those treated with the placebo, and (3) to insure blindness among PACE project personnel as to the kind of treatment applied until after the experiment and all analytical procedures have been completed.

The randomization scheme applies to experiment units within flights. No blocking according to weather type will be used, as was done in the 1986 experiment, since this type of blocking will neither result in a large or balanced sample. Balancing of the treatment will be undertaken by randomizing the experiment units in pairs such that no more than 2 experiment units will receive the same treatment in a row. Hence, we should avoid a major discrepancy between the number of seeded and unseeded samples obtained during the 1989 field program.

Two randomization schedules for the sequence of experiment unit treatments (Schedule A and Schedule B not to be confused or associated with Go-A days, Go-B days, etc) have been computed. Two tables for the random arrangement of flares by bank within the flare rack have also been computed. Each table of experiment unit randomizations was computed using the same randomization rules and an illustration of a randomization is shown in Table 1. In Table 1, the "+" sign has been used to indicate seeding (i.e., silver iodide flares are load into that bank of the flare basket) and the "-" indicates no seed (i.e., sand-filled flares are load into that bank of the flare basket). As can be seen in Table 1, during a typical operation, the sequence of randomization events indicates that the first experimental unit drawn in the randomization would receive Agl flares from bank 1. Assuming that flares in bank 1 are exhausted then flares from bank 4, would be used, then bank 5 and finally bank 8. Assuming, all flares of type "+" are used in the first experiment unit of the day, then the maximum number of experiment units for the flight is two.

Prior to the take-off for an in-target area missions, the randomization officer or his designee, will supply the in-flight meteorologist with two groups of envelops (one for schedule A and one for schedule B, since it might not be known until after the flight commences which table to use or both tables may be used during a flight). Each sequence of envelopes will reveal one-by-one the sequence of banks to use for each experiment unit for up to 4 experiment units for the flight. During a mission, within each experiment unit, only one envelope will be opened at a time to reveal the current bank from which to eject flares. This will help insure that no knowledge of the treatment sequence is inadvertently revealed to the aircraft crew.

Table 1. Randomization Table

Banks	Flt-1	Flt-2	Flt-3	·····	Flt-N
1	+	-	-	·····	-
2	-	+	+	·····	+
3	-	-	+	·····	-
4	+	+	-	·····	+
5	+	-	+	·····	-
6	-	+	+	·····	+
7	-	-	-	·····	-
8	+	-	-	·····	+

Exp. Unit	Flt-1	Flt-2	Flt-3	·····	Flt-N
1	+	-	-	·····	-
2	-	+	+	·····	+
3	-	-	+	·····	-
4	+	+	-	·····	+

The second experiment unit for Flight 1, as illustrated in Table 1, would receive placebo flares and treatments would begin with flares in bank 2, then 3, followed by 6 and if necessary 7. Assuming that all the flares for experiment unit 2 are exhausted, the aircraft would then have to return to base, the randomization for that operation would be expanded and the flare rack would be reloaded and a new seeding mission initiated if suitable clouds continued to develop.

Another possible scenario assumes that on a flight for whatever reason suitable clouds in the first experiment unit cease after only using a few flares in the first bank and, the search for a new experiment unit begins. Assuming that another unit is found, it is possible that suitable clouds cease to develop shortly thereafter, for example, slightly less than two complete banks of flares are expended. In the event a third experiment unit is found, then the next bank would be drawn from envelop three of the third experimental unit (see appendix).

a. Application of Randomization Schedules. Randomization schedules apply to the sequence of treatments used within the area of an experimental unit and choice of a randomization schedule will be independent and determined by visual cloud selection criteria for clouds within a potential experimental unit during a flight. Once selected, the same randomization schedule is used throughout the treatment of an experimental unit regardless of whether or not cloud behavior changes within the experimental unit. Under these rules, it is possible for the first experimental unit of a flight to use randomization schedule A while the second experimental unit of a flight might use randomization schedule B. However, it is more likely that on flights with more than one experimental unit the same randomization schedule will be used throughout. Procedures under randomization schedule A form the basic weather modification part of the 1989 field operations. It is this part of the 1989 experiment that will most likely evolve into the confirmatory experiment of PACE Phase 3.

Randomization schedule A will apply only to missions conducted within the target area using the Baron and only when "big" clouds are. developing in the target area (as defined for missions of Type I). These "big" cloud days refer to the upper part of the bimodal distribution of HiCu echo top data for natural clouds. The purpose using randomization schedule A for "big" clouds is to obtain a balanced sample of clouds, that probably have an active coalescence process, and would probably rain in the absence of glaciogenic intervention. The data set from these missions will form the primary set for analysis to discern seeding effects.

Randomization schedule B will apply to all other missions in which the clouds are to receive treatment. These missions are exploratory and assumed to be independent of "big" cloud missions. These types of missions will include: (1) Baron and T-28 missions when "big" clouds form in the target area, (2) on Baron-Only missions conducted in the target area when "small" convective cloud form (Tops ≈ 20,000) and (3) in the event seeding missions are conducted on either "big or "small" convective clouds which form outside of the target area, but within the state boundaries of Illinois.

For either randomization schedule A or B, a sufficient number of randomizations have been made in constructing both tables to insure that the maximum number of experiments feasible during the 1989 field program are included. Therefore, the randomizations process is finished and no more randomizations will probably be required before the field program terminates.

From this randomization process, four different types of data sets for treated clouds will be produced from PACE89 operations, three of these will be formed from radar observations in conjunction with aircraft measurements and one of these will be formed from aircraft only. The first data set, created from missions referred to as Type-I Missions, will depend on use of randomization schedule A. This draw of the treatment schedule will produce a data set on echo core behavior for "big" cloud days when aircraft maneuvers involving only the Baron occur within the "good" view of the radar. These data will provide the basis for primary objective of PACE89; *to discern seeding effects using radar derived response variables and at the same time provide a physical basis for the analysis from in-cloud measurements.*

The creation of all remaining data sets on treated clouds will rely on utilization of randomization schedule B.

The second data, created from missions referred to as Type II, will be drawn from days in which aircraft maneuvers using only the Baron, are performed on "small" clouds developing within the "good" view of the radar. These data will form the basis for study of in-cloud reactions to AgI seeding and may provide information regarding explosive cloud growth, "cut-off" tops and the utility of seeding to overcome mid-level stable and dry layers.

The third data set, created from mission referred to Baron only of Type III, will also rely on randomization schedule B for treatment of "small" and "big" congestus type clouds that form outside the target area. Data collected during these missions will serve a utility similar to Type II.

Finally, randomization schedule B will be used on days when the T-28 and the Baron fly together (referred to as missions of Type V) to monitor water to ice conversion at constant altitude in treated and non-treated "big" clouds. Since the on-station time of the T-28 is relatively short, it is expected that these days will transform into missions of Type I. However, randomization schedule B will remain in effect until no more experimental units exist. Although it is expected that adoption of this procedure will lead to an imbalance between treatments in the sample, the imbalance will be small since the number of T-28 and Baron missions should be few; limited by the number of available weeks of T-28 time and the number of weather opportunities.

b. Flare Handling and Access. Randomized sequences for experimental units and for the sequence of treatments by banks in the fl'are racks have been accomplished for each potential flight, assuming that at least one to a maximum of four experimental units might be treated on each flight (see Table 1 for an illustration). For each flight, the aircraft will be equipped with two flare baskets each holding 100 flares each, for a total of 200 flares in the flare rack. The 200 flares are arranged in 7 banks of 26 and 1 bank of 18 flares. Each bank is randomly selectable, however the first flare to be fired within a bank is not randomly selectable. Therefore, the first flare to be fired within each bank will be flare number one. It will not be permitted to go back to a previously used bank and use flares in that bank.

The flares are stored under lock and key in an area of the Project Headquarters (Q6). The initial purchase of flares (1200) is distributed among six boxes nearly identical in their marking. Each box contains an equal number of AgI and sand flares. Although the purchase arrangement for the flares was conducted by key personnel in PACE, the flare contractor has informed only the experiments principle scientist (Stan Changnon) of the code used to distinguish between sand and silver iodide flares in each box. In turn, the principle scientist has only informed the randomization officer in PACE (Floyd Huff). The flare technician (i.e., person responsible for loading and unloading baskets and mounting and dismounting of flare baskets onto the airplane) will be informed of only the arrangement of code by flare bank within each basket and ordering of baskets on the aircraft, not the meaning of the code.

To further blindness of the treatment type, flares have been intentionally constructed so that a minimal difference exits between the noise resulting from firing a flare made from sand and the noise made from silver iodide. No one other than the randomization officer, flare technician, and if need be a representative of the aircraft contractor, is permitted in the area around where flares are being handled be it in Q6 or around the airplane when the flare baskets are being mounted.

Similarly, after a mission has been completed access to the areas of flare handling is similarly restricted. Upon completion of each mission, an inventory of the flare baskets will be conducted and the number of flares used in each bank and the number of "dud" flares in each bank will be recorded. These numbers will be released during mission debriefing and used to construct an accurate flare accounting for each mission. Aside from keeping written notes as to the suspected type of treatment for each unit, persons are discouraged from discussion of this aspect of the experiment. However, some discussion of the suspected treatments may be necessary to improve operations.

No information on the randomization will be accessible to anyone involved in the treatment (seeding) operation, data preparation and analysis. Information regarding the details of the randomization sequences will be made public only after all analytical results are ready for the crucial seed vs. no-seed comparisons.

5. Aircraft Operations

a. Baron Only of Type I. Generally, a flight plan will be filed from CMI to a predetermined way point at 20,000 ft. Assuming that the way point is within or as been adjusted to be within a field of suitable convective clouds, a first penetration will be made to test for suitable in-clouds conditions, followed by a series of treatment (and when permissible post-treatment) penetrations. All first penetrations for seeding will be made near the -10°C level with no more than 5000 ft of cloud top above the initial level of cloud entrance. Relative aircraft position to cloud top will be noted and recorded. Typically, the aircraft will set up for a penetration approximately 1.5 km from the penetration of cloud and fly a straight and level course to cloud edge (this will result in approximately 10 to 15 seconds of cloud environment measurements). Ideally, cloud penetrations will be made at a fixed angle to the vertical shear of the horizontal wind. Upon entering cloud, the aircraft will be allowed to float with the rising and sinking air currents and turns will be kept to a minimum. Upon exiting cloud, the airplane will fly a straight and level course for approximately 10 seconds before a turn is initiated and another cloud suitable for seeding is sought after. Assuming a new cloud is found, this maneuver repeats until, either no more clouds suitable can be found, the experimental unit terminates, or weather conditions dictate the cessation of seeding.

b. Baron Onlv of Type II. These missions occur on days when "small" cloud form in the target area. The airplane will depart CMI and head for a predetermined way point at an altitude near the -7°C level. Upon identifying a suitable cloud, the airplane would follow a straight and level course to the selected cloud of approximately 1.5 km before cloud penetration. Seeding material will be released while in-cloud. The airplane will be allowed to float with the vertical motions of the cloud and follow a straight course keeping turns to a minimum. Upon exiting, the airplane will be kept in straight and level flight for at least 10 seconds before initiating a turn. Second, post treatment penetrations at slightly higher altitude, (near -10°C) approximately 4 minutes after treatment are desired for collection of data on in-cloud reactions to AgI treatment. A second penetration initiates with the an aircraft climb to approximately 20,000 ft. Procedures for the first penetration are then followed. Upon, completion of the second penetration a new cloud for treatment is sought. If a new cloud is found then the airplane will descend to -7°C and the maneuvers as just described is repeated. If a new cloud can not be found, and if safety permits a third penetration may be initiated. Seeding is performed on first penetrations only.

c. Baron Only of Type III. These are out of target missions (but in Illinois) in which clouds are treated. If "big" clouds are found then the rules of Baron Type I missions are followed. If "small" clouds are found, then the rules for Baron Mission Type II are followed.

d. Baron Only of Type IV. These are out-of-state missions conducted for the purpose of collecting data on natural clouds processes and no seeding will be performed. No seeding will occur in that portion of the target area which encompasses west-central Indiana, although it is permissible to seed clouds developing in eastern Illinois that show advection toward Indiana; since we have no way to know whether these clouds would ultimately cross the Indiana-Illinois state line.

Flights out side the target area will only be conducted on days when conditions in the target area show no hope for the development of suitable convection, and when an extra-target area mission can provide valuable supplementary data on in-cloud mixed-phased precipitation processes and in-cloud dynamics. A specific flight plan will be set before each mission.

e. Baron and T-28 Missions of Type V. These missions occur when "big" clouds are developing within range of the radar; up to 90 km, preferably 50 km. Aircraft file for a flight of two and fly formation to a predetermined way point at approximately 20,000 ft. Assuming that suitable clouds are developing within this area, the Baron makes a first/treatment penetration of a suitable cloud according to the rules of Type I, except no test cloud is required. Upon exiting cloud, the Baron would fly a safe distance away and the T-28 would initiate a series of penetrations of the treated entity at approximately -10°C. Upon completing the series, if time permits, another cloud will be chosen by the Aircraft Director, and this maneuver would be repeated. Otherwise, the Baron would transfer to a Type I mission, under randomization schedule B.

f. T-28 Missions Only Type VI. On these missions the T-28 would file to a predetermined way-point within a area of suitable convection. In coordination with the radar, a suitable cloud for monitoring would be selected and the T-28 would initiate a series of penetrations of the same echo core to monitor its evolution. If the 55 dBZ level is reached, penetrations would end. If possible, a second echo core would be identified and the T-28 would repeat this maneuver. It is likely that the T-28 will experience structural icing sufficient to warrant aircraft decent to a warmer altitude. In this event, time permitting, a new echo core would be identified and the T-28 may initiate a series of lower altitude penetrations.

6. Radar Scanning Procedures

The CHILL radar will be the primary radar for the PACE 1989 operations. It is anticipated that the HOT radar, also a 10-cm Doppler radar will be running by 1 June 1989 and will be operated in a surveillance mode, i.e., 360° scans, topping all echoes. When both radars are operating at the same time, they will both have to by pass the azimuth sectors where they point at each other. However, because the CHILL will be able to drop its surveillance task, it is felt that this is a small cost. Additionally, both radars must by-pass an approximately 5° wide sector directed at the airport tower (SW of the radars) at the lowest elevation angles. The CHILL effectively causes the airport tower printer to go 'off-line'. This is unacceptable to the tower control. It is unlikely that a shield will resolve the problem.

The CHILL radar will collect reflectivity, velocity, and differential reflectivity (ZDR) measurements on a routine basis. Additionally, when the aircraft are flying, the CHILL will record: 1) the aircraft positions, and 2) when the Baron is seeding, the centroid of the experimental unit as well. The ground clutter filter will be used at the lowest elevation angle, within 37 km of the radar.

The radar scanning procedure has been devised in order to 1) rapidly collect data (within 2-4 minutes per volume), 2) top the echoes of interest, 3) obtain ZDR measurements, and 4) to collect reflectivity measurements for the calculation of rainfluxes.

First, for each volume period (except during the most intense aircraft phase), a 360° low level (.5°) elevation sweep will be made. This is to ensure that the radar is surveying all possible convection, and to collect data for rainfall studies. If the echoes are distant enough to be topped in less than 4 minutes doing 7 elevation sweeps (1° steps), the radar will be run at a rate of l2°/sec, with PRT of 1040.

In order that ZDR be of sufficient accuracy (> .1 dB standard deviation in most cases; .15 dB standard deviation when more than 7 360° sweeps are required), it has been decided that along a radial, every 2 range gates of 150 m depth will be averaged together prior to the data recording step. It is believed that this (300 m) will give sufficient spatial resolution for comparison with the aircraft data. Thus, all PACE PPI data will be of 300 m gate resolution. This will allow us to run the radar at a reasonable speed for surveillance, 12°/sec, instead of 6°/sec as well as to collect ZDR data. It is possible that the RHI data will be based on 150 m gates sinc'e the time required for RHIs is much less; a standard sweep rate is 2-8°/sec for an RHI.

Once the aircraft are scheduled to be launched, and when the echoes are reaching heights not attainable by 7 elevation steps, the radar will begin sector scans above the .5° 360° elevation sweep. It is hoped that the sectors will be wide enough to cover and top all convection of interest, but narrow enough to complete a volume in less than 4 minutes. As the aircraft are nearing the clouds of interest, the sector may be further narrowed. While aircraft sampling/seeding is in progress it is our goal to complete a volume scan in 2-3 minutes. Only during this period, the low-level 360° sweep will be made every other volume (i.e., about every 3-minutes). With a sector of 120°-180° this is very likely. After aircraft operations have ceased, volumes of up to 4 minutes will again be allowed. The radar will continue recording until the experimental unit rainfall has dissipated or moved off the scope and other convection of interest has dissipated, probably 1-2 hours after the aircraft have returned.

The scan procedure may be modified if time (real time) permits the inclusion of occasional RHIs. Also, if the echoes of interest are too near to the radar (30-40 km), to be topped by 12 1° elevation steps, the steps above 6.5 may be increased to 1.5 to 2.0°. If it is necessary to top echoes with more than 12 steps using 360° sweeps, the azimuth step (normally 1°) will be increased to 1.1 to 1.2°, and the antenna speed quickened to accomplish this. The elevation optimizer software will be used if all echoes are within 60 km.

The radar data will be displayed in real-time in 2 ways. First the 360° sweep will be stored every volume so that it can be recalled when a description of the cloud field is required. Secondly, a magnified view of the area of interest will be displayed so that cell motions (experimental unit motions) can be computed and so that the seeded echoes and experimental units can be tracked.

The radars will be calibrated routinely. The receiver will be calibrated at the end of every operation. It is planned that the ZDR isolation will be checked both before and after every operation.

The following morning, the tapes from the previous day will be inventoried and the data replayed. This will insure that most data problems will be caught quickly. If possible, the low level elevation sweep will be video taped. Tape copying for data processing will be accomplished on down days.

7. Conditions for Terminating Seeding Operations

Severe weather conditions will be used to alter operations under the following criteria:

1) No treatment will be performed within 50 nautical miles of a Severe Weather Warning Area or within the same convective system with a valid Warning even if located at a greater distance;

2) Treatment shall be terminated within an experimental unit if a severe weather warning is issued that includes part or all of the experimental unit;

3) Treatment shall be terminated within an experimental unit if either the pilot, in-flight meteorologist, or radar meteorologist assesses that the potential for violent convection, is significant.

In the event that treatment is terminated within an experimental unit, penetrations of clouds are permitted in order to collect data on "natural" cloud properties.

Treatment will be allowed in areas covered by a Severe Weather Watch; however, all personnel will be advised of these situations when they occur and asked to pay special attention to the developing potential for severe weather.

OPERATIONS

1. Operation Period

The 1989 operational period will begin on 8 May 1989 and extend thru 28 July 1989. In the event that cloud-less conditions prevail during most of the operational period, operations may be extended to 11 August 1989 to seek to increase the sample number of clouds. The field operations will be brought to a conclusion with a general PACE staff meeting in the morning of 31 July 1989 (or 12 August) to set operation shut-down assignments and to set initial research and analysis priorities.

2. Operational Process

See Decision Tree, shown in Fig. 4.

3. Operational Base

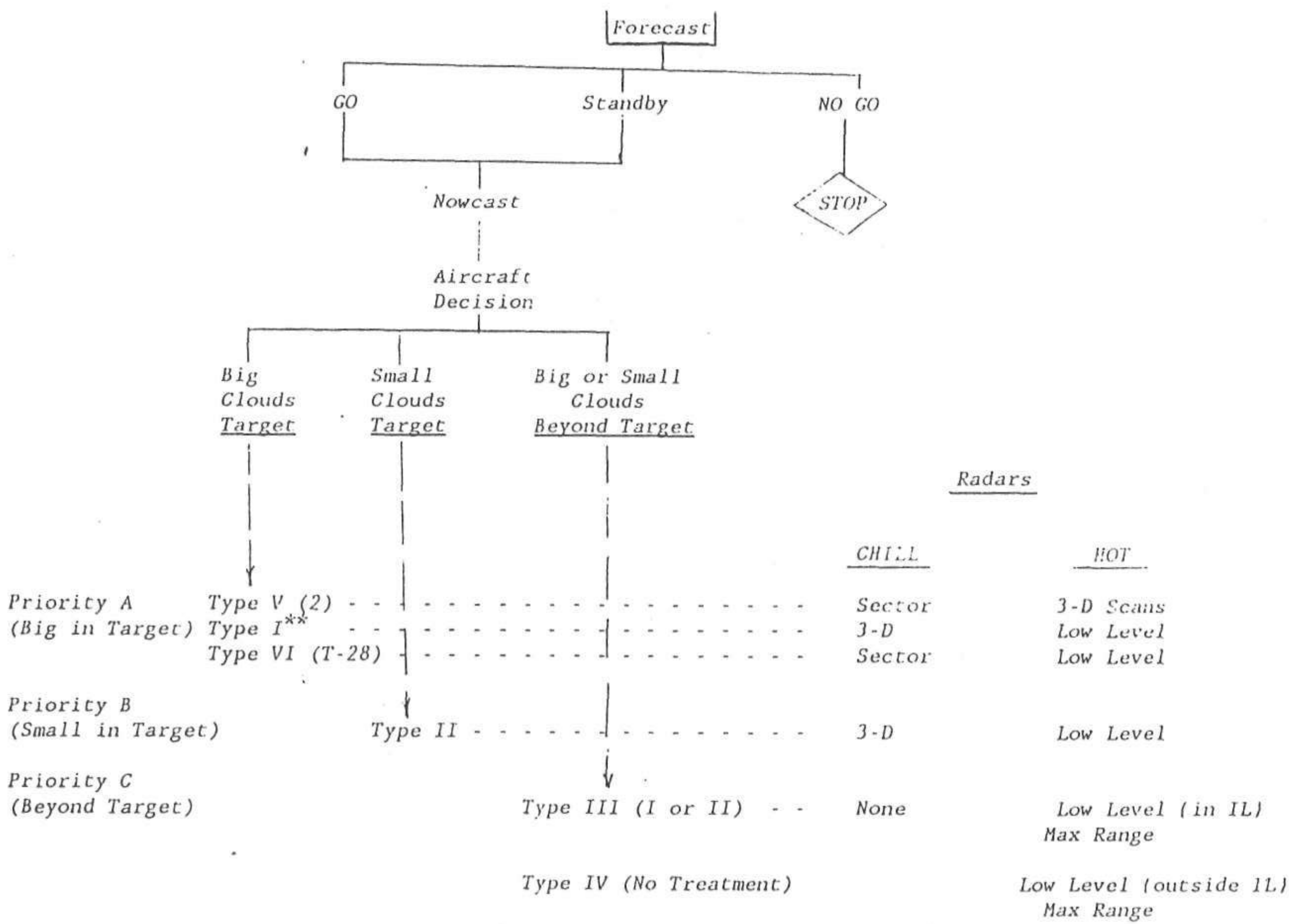
The PACE experiment is based at The University of Illinois Willard Airport (CMI) and encompasses the area of a circle with radius approximately 100 nautical miles (see Fig. 1).

4. Mission Control

Mission control will be in the CHILL User Van. During aircraft missions, access to the CHILL User Van Shall be restricted to those directly involved with mission control. Access is restricted to:

1) The Radar Meteorologist. This person shall be responsible for designating and monitoring the experimental units of the flight. This person shall also be responsible for selection of radar scanning procedures (Westcott/Brunkow).

DECISION TREE FOR OPERATIONAL PERIOD*



* or more per day is possible
.t common ch·ice except for May

Figure 4. Experiment Priority Chart

2) The Radar Controller. This person shall be responsible for impleraenting radar scanning procedures and for generally assisting the Radar Meteorologist (Kennedy/Brunkow).

3) The Aircraft Meteorologist. This person shall be responsible for communication between aircraft and mission control and shall be the intermediary by which messages are sent between aircraft and mission control. This person shall also be responsible for maintaining a detailed record of radio communication (Daining/Miller).

4) The Nowcaster. This person shall be responsible for providing current assessments of the weather and its expected short term behavior. Although, this person shall also be responsible for checking current weather conditions against the criteria for suspension of seeding operations, public safety is the responsibility of everyone (Scott/Entwhistle).

5) Mission Observers. Generally, it will be permissible for one or two people to observe the conduct of operations during the course of a mission. However, persons are present at the pleasure of the Radar and Aircraft Meteorologist and either of these mission control personnel may ask observers to leave without explanation.

6) Project Director/Operations Coordinator (Czys/Changnon).

5. Daily Schedule

Daily Schedule for PACE89 (all times in CDT).

0700-1000	:	Duty forecaster prepares forecast for 1200-2100, and outlook for. next few days
0930	:	Radar on and ready for operations based on the preceding days forecast and on days of unforecasted convection
0900-1000	:	Aircraft crews assess status of equipment
1000-1030	:	Briefing, status report and discussion (all duty staff attend)

1. Weather briefing by duty forecaster
2. Equipment status reports and time back
    a. aircraft by pilots and other crew members
    b. randomization officer
    c. radar status by duty radar meteorologist and chief engineer

3. Decision for the day, done by operational coordinator with input from nowcaster, seeding aircraft director, and radar director, with 3 options:

   a. no go during 1200-2100 for the day
   b. launch all systems by 1200 or some other designated time
   c. standby for possible later operations during the 1200-2100 period

4. Plan flights, call FAA

1030-1100
(or later) : Debriefing led by duty nowcaster. This will be done if needed in relation to prior days operations, and if there are no immediate operations. The. debriefing will be done by responsible duty staff as follows:

1. Recap of overall operations by nowcaster

2. Recap of yesterday's forecast and outcome by duty forecaster

3. Recap of radar operations by radar duty meteorologist

4. Recap of flight operations by aircraft crews

5. Status of data collection and data archival by data base manager

1100-1200/
1130 : Loading of flares, if needed, and randomization instructions by randomization officer and assistant to Flight Director

1330 : CLASS radiosonde release by duty forecaster/assistant

1200-2100 : Potential operations. Possible options after one unit of treatment includes a second or third treatment period based on nowcaster decisions which will involve real-time discussions with Flight Director and other aircraft crew on status

1700 : If the morning outlook suggests possible cloud opportunities on the following day, the nowcaster will assess, in the evening, the likelihood of early operations and present his decision by or at the end of operations. Personnel will call in to his recorded message for the decision.

6. Communications

a. Radio. The PACE Project has been authorized by NOAA to broadcast using 171.8 MHz for air-to-ground communication between the CIC Baron and the Operations Control Center (CHILL User Van). This temporary licence issued from the Department of Commerce permits the use of a ground station with 64 watts transmission power and the use of mobile FM transceiver of up to 40 watts power. In accordance with the Department of Commerce authorization, the PACE Project is the responsible party for this frequency and a copy of the license is on site and a part of this operations plan. In the event of project termination the Frequency Management Office of NOAA in Boulder will be notified.

Air-to-ground communication between the SDSM&T T-28 and Operations Headquarters will be transmitted using the frequency of 122.925 mH_3. During missions when both the CIC-Baron and the T-28 are air born the primary communication frequency will be that of the T-28 and instructions from T-28 to the Baron will be transmitted over pilot-to-pilot VHF. Communication with air traffic control will be the responsibility of the Baron during two aircraft missions.

b. Telephone Directory.

PACE General Access: 244-8619 or 244-8678

PACE Project Personnel:		Home Phones
S. Changnon (Room 606) 244-8678	SWS = 244-0494	1-586-5691
B. Czys (Room 606) 244-8678		337-0905
B. Scott (Room 603) 244-8719		356-3435
N. Westcott (Room 605) 244-8674		344-0693
G. Achtemeier (Room 603) 244-8719		352-1387

Radar Personnel:

D. Brunkow (Room 608)	244-8639	359-0229
P. Kennedy (Room 604)	244-8699	356-1663
E. Mueller (Room 601)	244-8619	352-8632
J. Nespor (Room 607)	244-8629	359-2682
D. Oliver (Room 609)	244-8659	355-1319
A. Sims (Room 608)	244-8639	356-1725
D. Staggs (Room 607)	244-8629	325-9606

Mission Control (CHILL User Van):

244-8619
244-8739
244-8740
244-8743
244-8759

Project Headquarters (Q6):

Q6 Machine Shop: 244-8659
Q6 Electronics Shop: 244-8649

FACILITIES

1. Project Aircraft

The cloud seeding/cloud physics aircraft used in PACE for the duration of the operations is a small twin-engine Beechcraft Baron leased to us from Colorado International Corporation (CIC). The performance characteristics are listed in Table 2 and the instruments are listed in Table 3.

The South Dakota School of Mines and Technology T-28 will also support project objectives. This airplane is armored for penetration into severe thunderstorm regions and will be used to obtain data on the later and presumably severe stages of echo core lifetimes. The performance characteristics of the T-28 are listed in Table 4 and the instrument package is listed in Table 5.

2. Forecasting/Nowcasting

A. Zephyr Weather Data

Most of our basic weather data will be received via satellite from Zephyr Weather Service of Westborough, MA. A 12-ft receiving antenna, installed in 1986 within the main office complex of ISWS, serves as the data reception point for the weather data. This location is directly adjacent to the ISWS's VAX 11-750 computer into which much of the data from Zephyr will be directed and archived.

Two types of weather data are received from this source: DIFAX facsimile charts and the NWS Domestic Plus weather circuit.

1. DIFAX Facsimile Charts

Meteorological charts prepared by the National Meteorological Center (NMC) will be received continuously via the DIFAX line. These are hard copy weather charts that are transmitted according to a schedule set at NMC. They include, in part, surface and upper air analyses, radar summaries, and a large variety of forecast fields generated from computer models run at NMC.

These charts will be of greatest important in the forecasting operations although the nowcaster will certainly have access to them. Most likely, however, they will serve as the main focus of the daily weather briefing, giving a large-scale view of the synoptic controls in place at a particular time. Maps scales range from hemispheric to the contiguous United States. Updated charts vary, depending on type; radar summaries appear hourly, surface charts are plotted every 3 hours, while new upper air and forecast charts are available twice a day.

2. NWS Domestic Plus Weather Line

The NWS Domestic Plus weather circuit includes substantial digital and worded information. Important data in this set are twice daily upper air soundings, hourly surface observations, and hourly radar reports from across the United States. These data are fed directly into the ISWS's VAX computer and are utilized to generate rapid analyses of current data for forecasting/nowcasting operations.

Several programmed calculations currently available include: 1) regionalized surface analyses of pressure, temperature, dewpoint, streamlines, isotachs, and divergence, 2) upper air analyses of height, vorticity, wind speed, moisture, and thickness, and 3) local sounding work-ups of Skew-T Log-P

Table 4

BEECHCRAFT BARON MODEL 58-TC, N23712

PERFORMANCE DATA 1989

Power, each engine	325 hp
Maximum speed	235 kts
Fuel capacity	175 gal
Service ceiling	25,000 ft
Single engine service ceiling	13,000 ft
Climb at gross wt	1500 ft/min
Maximum endurance	5 hrs
Maximum range	900 nm
Take-off distance	2400 ft
Landing distance	2500 ft
Gross weight	6100
Empty weight	4570
Seating (Restricted Category)	3 crew
Length	30 ft
Wing span	38 ft

Table 5

Aircraft Instrumentation 1959

Parameter Measured	Instrument Type	Manufacturer and Model Number	Combined Performance of Transducer, Signal Conditioning and Conversion: Range	Accuracy	Time Constant	Sample Rate	Useable Resolution
Time	Crystal osc	PMS	12 mo	is	N/A	0.1s	0.1s
Tcnperature	Platinum resistance, Deiced	Rosemount Eng. Co. 510BF9 Bridge Model 102 Probe	i50° C	0.5° C	1	1Hz	0.1 C
	Solid State reverse flow	NCAR - Probe AD 590 element	± 50° C	0.1° C	.1	10Hz	0.1° C
Dew Point	Peltier cooled mirror	Cambridge Systems Inc. Model 137-C3	± 50° C	1° C	1-5 s	10Hz	0.3°
Liquid Water	Hot wire (Johnson-Williams)	Cloud Technology Model LWH	0-3 gm/m^3	0.2 gm/m^3	1	10Hz	0.01 gm/m^3
Cloud Particle Size Concentration	Optical Scattering	PMS FSSP	1-45U .l-1500cn^{-3}	3u 102	Discrete Event	Continuous	lu .1 cn^{-}
Cloud Size & Concentration	Optical array, imaging	PMS 2-d OAP	25-800u 0.1-10.000L^{-1}		Discrete Event	Continuous	25u 0.1L^{-1}
Cloud Preclp. Size & Concentration	Optical array imaging	PMS 2-d OAP	200-6A00u 0.1-10,000L^{-1}		Discrete Event	Continuous	200u 0.01L^{-1}
Vertical Velocity*	Computed						
Angle of Attack	Differential pressure	Rosemount Model 858 & 1201	± 20°	0.25°	0.1	10Hz	0.1°

*Vertical velocity is computed, using the angle of attack and true air speed measurements from a nose boom, pitch and integrated vertical acceleration of the airplane.

			Combined Performance of Transducer, Signal Conditioning and Conversion				
Parameter Measured	Instrument Type	Manufacturer and Model Number	Range	Accuracy	Time Constant	Sample Rate	Useable Resolution
Side Slip	Differential pressure	Rosemount Model 858 & 1201	±20°	0.25°	0.1	10Hz	0.1°
Pitch	3 axis Gyro	Honeywell Model J670 44A-4	±19.5	0.5°	0.1	10Hz	0.08°
Vertical Acceleration (Airplane)	Pendulous mass	Sundstrand Corp.	±2g	0.001g	0.01	10Hz	0.001g
Indicated Airspeed	Differential pressure	Rosemount Eng. Co. Model 1332B1	±2.5 psid	0.0025	0.1	10Hz	0.0025 psid
Heading	3 axis Cyro	King KCS305	0-360°	0.5°	0.1	10Hz	0.1°
Altitude	Total pressure	Rosemount Eng. Co. Model 1241	0-15 psia	0.015 psia	1	1Hz	0.007 psia
Position (azimuth)	VOR	King Radio	0-360°	+1°	0.1	10Hz	0.1°
(distance)	DME	King Radio	0-300km	0.2km	1	10Hz	0.1km
Position	Loran-C CIC Interface	ARNAV R-21	0-9999nmi	0.5km	1	1Hz	0.01km
Events	Digital latch	PMS	3 events	is	Discrete	Continuous	is

Parameter Measured	Instrument Type	Manufacturer and Model Number	Specifications
Phocography	Video Camcorder	Olympus	
Data Recording	Mag Tape	Pertec	9-track 1600 BPI Encoded
Real Time Processing	Video	Kono	Cockpit Display of parameters updated every sec.
	Hardcopy Printer	MPI	Hardcopy updated every sec.
Floating Air Parcel Tracking			True airspeed, heading integration corrected for sideslip and angle of attack. Nominal accuracy is 0.5km for 20 min.

diagrams, various stability indices, and a 1-D cloud model. Hard output of all these data will be available via a high speed modem connected to a multi-pen flat bed plotter.

In addition, the Domestic Plus weather circuit will provide the operational staff with important up-to-date information on the forecast or occurrence of severe weather in our vicinity. These data are necessary to help insure the safety of both personnel and equipment involved in the field operations. Specific messages to be monitored are daily severe weather outlooks, current weather summaries, special weather statements, and severe weather watches and warnings across Illinois and adjacent states.

B. GOES Imagery

Near-real-time visible cloud images as observed by the Geostationary Operational Environmental Satellite (GOES) will be obtained via a telephone-link to the Man Computer Interactive Data Access System . (MCIDAS) at the University of Wisconsin, Madison. The data are received in digital form, then reconstructed using an IBM PC/AT and displayed on an IBM Professional Graphics Display screen. The monitor is a high quality display system which will create images using 16 gray shades. There is no looping capability of the system, therefore, operational use of this system will depend on Polaroid photographs of the images for cloud pattern continuity.

These data will be received in two spatial resolutions. Four-km resolution images will be available to retrieve every two hours from 0730-1930 CDT. These images cover, in general, the eastern two-thirds of the United States. One-km resolution images will be available every hour from 0800-1200 and then at half-hour intervals during each operational period. These images cover the state of illinois with some adjacent areas of the states to the east and west. Images will be available to participants about 20-25 minutes after the observation.

C. CLASS Soundings

The CLASS (for Cross-Chain Loran Atmospheric Sounding System), is a one-man, semi-automated rawinsonde unit developed by NCAR/GAMP. It tracks a light-weight meteorological sonde carried aloft by a helium-filled balloon which then transmits thermodynamic data back to the ground. The system, includes a computer for initialization procedures, real-time display during ascent and data archival. The unit is self-contained in a small trailer modified which permits launching of the balloon through a retractable hatch in the top of the trailer.

Tracking of the sonde is accomplished by Loran navigation from multiple sites. Wind are calculated by least-squares solution of the difference in the arrival times of the multiple signals. Data are collected at 10-sec intervals with 30-sec averages stored on disk. After the flight, the average data can be transferred via telephone to the ISWS VAX for further analysis. The Loran tracking system performed quite well in previous operations located at CMI (1986, 1988).

3. Radars

(See Table 6).

Parameter	10-cm Channel	3-cm and 10-cm Channel	3-cm Channel
Antenna			
Shape	Parabolic		Polarization twist Cassegrain fe
Diameter	8.5 m		2.5 m
Half-Power Beamwidth	.96		1.0
Gain	43.3 dB		39 dB
First Side Lobe Level	-25 dB		-30
Polarization	Horizontal and vertical on pulse to pulse basis		Horizontal
Azimuthal Antenna Rotation Rate	30 °/s		Same
Antenna Controller			
PPI Capability		Yes	
Sector Scan with Variable Limits		Yes	
Azimuthal Sample Spacing		Unlimited	
Elevation Increment		Unlimited	
RHI		Yes	
Transmitter			
Wavelength	10.7 cm		3.2 cm
Frequency	2.73 GHz		9.375 GHz
Peak Power**	1 MW		100 kw
Pulse Width	0.25, 0.5, or 1.0 um		1 usec (150 m)
Pulse Repetition Time-Equispaced*	800-2500 us		1056/1230 μs
Maximum Unambiguous Range	375 Km		
Maximum Unambiguous Velocity	±34.4 m/s		
Receiver			
Noise Figure	~ 4.0 dB		13 dB
Transfer Function	linear		logarithmic
Dynamic Range**	90 dB		55 dB
Band Width 3 dB	Varies with P.W		1.2 MHz
Min. Detectable Signal (SNR=1)**	-110		-98 dBm
Data Acquisition			
No. of Range Gates	1024-4096		1024-4096
Range Gate Spacing	0.25, 0.5, 1.0 us		1 μs
Recorded Word Length			
Velocity	8 bits (2's comp)		
Width	8 bits (binary)		
Intensity	8 bits (binary)		8 bits (binary)
Ground Clutter Canceller	Not decided		No
Number of Samples in Estimate	Arbitrary		Arbitrary
Tape Recording			
Format		Almost Universal Recording	
Tape Density		6250 cpi	
Block Length		≤ 8192	
Initial Variables Available***			
Reflectivity	Yes		Yes
Horizontal Polarization	Yes		Yes
Vertical Polarization	Yes		No
Cross Polarization****	Yes		No
Differential	Yes		No
Velocity (from pulse pair algorithm)	Yes		No
Width (from 2nd lag pulse pair algorithm)	Yes		No
Correlation functions with lags of 1	Yes		No
Normalized Coherent power	Yes		No
Doppler Spectra from FFT processing	Yes		No

* A pulse repetition staggering is possible permitting larger unambigious ranges

** Representative value

*** Other variables or variants of these variables can be obtained by reprogramming of the preprocessor

**** With accuracy reservations

PROJECT MANAGEMENT AND PERSONNEL

The PACE project is staffed by the following people, each having the responsibility indicated. When the Project Director is on site the Project Director also is Operations Coordinator.

The project personnel, by title/assignment, are listed below with the backup staff listed second.

PACE/ISWS:

Project Director: Stan Changnon
Operations Coordinator: Bob Czys/Stan Changnon
Director of Aircraft Operations: Bob Czys/Pat Kennedy
Director of Radar Operations: Nancy Westcott/Dave Brunkow
Director of Forecasting: Bob Scott/Gary Achtemeier
Data Management: Michelle Miller/Harry Ochs
Randomization Officer: Floyd Huff/Stan Changnon/Robin Shealy
Flare Technician: Matt Walter/Jim Daining
Technical Director: Harry Ochs
Nowcaster: Bruce Entwhistle/Bob Scott
Radio Communications: Jim Daining/Michelle Miller
CHILL Radar: Gene Mueller
HOT Radar: Jerry Nespor/Don Staggs
Radar Controller: Pat Kennedy
Radar Assistants: Darnell Oliver/Art Sims

Colorado International Corporation (Beechcraft Baron):

Norman Ostrander - Pilot
Don Stone - Instrument Technician

South Dakota School of Mines and Technology (T-28 Aircraft):

Dennis Musil - Project Meteorologist
Andy Detwiller - T-28 Facility Scientist
Ken Hartman - Computer Programer
John Leigh - Aircraft Mechanic
Gary Johnson - Electrical Engineer
Daniel Custis - T-28 Pilot

DATA MANAGEMENT

Data management is the responsibility of the ISWS and all data collected except that by the T-28 becomes the sole property of the ISWS. Any use or disseminate of the data is prohibited without prior written approval of the ISWS.

The group in charge of each observation facility, whether that be the CHILL, HOT, CIC-Baron, or T-28 is responsible for devising a system which catalogs the data, instrument performance, type of data storage (weather maps, tapes, disks, film, etc) and the location of data storage at the end of each mission. This catalog and data sources will be turned into the Data Manager. It will be the responsibility of the Radar Meteorologist to create a master file sufficiently detailed to permit project personnel to find data for later analysis.

Airport Telephones

	06	Radar Van	User Van	HOT	
244-8619	X	X	X		
244-8739		X			(RATS)
244-8743			X		
244-8740			X		
244-8629				X	

Personnel

	Office	Home
Czys	244-8678	337-0905
Changnon	244-8678	586-5691
Scott	244-8719	356-3435
Huff	244-8699	398-4321
Westcott	244-8674	344-0693
Kennedy	244-8699	356-1663
Mueller	244-8619	352-8632
Nespor	244-8629	359-2682
Staggs	244-8629	352-9606
Brunkow	244-8639	359-0229

244-8719 - basically for visitors and recorded forecast

359-5211 - Control Tower

303/497-8772 CLASS in Boulder

May 12, 1959

Memo to: Bob Czys

From: Floyd Huff

Subject: Combination of Type A and B Experiments on Same Flight

The possibility exists that you might desire to shift from a Type A to a Type B exgeriment during a given experimental flight (or vice versa). For example you might conduct Type A experiments on experimental units 1 and 2. Then, a need to shift to a Type B experiment might occur.

In the above case, the first Type B experiment would be the third experimental unit treated on the flight. Therefore, the set of envelopes for experimental unit 3 (L-l to L-4) should be used(not experimental unit 1). This is necessary to preserve our randomization scheme, and insure blindness.

In other words, maintain the sequence of experimental units even though a change in experimental types has occurred.

copy to: SAC

A Division of the

Illinois Department of Energy and Natural Resources

T-28 Meteorological Research Measurements

Parameter	Instrument	Accuracy (absolute)
Pressure	Rosemount 1301 (2)	± 1 mb
Static Temperature	Rosemount De-iced Total Temperature Probe	± 0.5°C
	Reverse Flow Temperature (NCAR)	± 0.5°C
Particulates and Hydrometeors	PMS FSSP (1 - 57 μm)	± 20% cloud water concentration ± 2 μm particle size
	Johnson-Williams Cloud Water Meter (1 - approx. 30 μm)	± 20% cloud water concentration
	PMS 2D-C (27 μm - few mm)	± 50% precip water concentration ± 14 μm particle size
	Foil impactor (Williamson) (1 mm - 1 cm)	± 50% precip water concentration ± 100 μm particle size
Vertical Air Motion	(derived from aircraft equation of motion)	± few m/s
Ambient Electric Field	N.M.I.M.T. shutter-type electric field mills (vertical and transverse)	approx. 2X
Aircraft Position	V0R/DME (1) (2)	± 5% of distance from VORTAC

RADAR OPERATIONS

1)To inform CHILL Field Facility manager/chief radar engineer of eminent operations, and in case of morning operations of a decision to initiate abort operations.

2)During operations to inform aircraft scientist/ nowcaster of radar status.

3)To provide aircraft scientist with info on echo locations, size, strength, echo motion(steam & cell)

4)To relay info to radar antenna controller on desired scanning modes; to initiate/terminate data recording.

5)To track experimental units & the treated storms within, in time; to provide aircraft with info on status of experimental unit & it's buffer zone, with regard to storms within the unit and to location with respect to Indiana, to severe weather warnings, to other potential units, to the radar(i.e. too close, too far)

6)To provide info on other best potential experimental units, sometimes deciding on the modification of experimental unit shape.

7)To determine end of operations.

8)To write up radar description for an operational day.

9)To provide summary(times, fields) of radar data collected.

PYROTECHNIC DEVICE MANAGEMENT

Description of duties from mission declaration to aircraft shut down.

1)Select appropriate randomization envelopes and give them to the aircraft meteorologist.

2)Select preloaded flare racks by flight and experiment type.

3)Install flare racks on aircraft when pilot gives his O.K.

4)Retrieve randomization envelopes from meteorologist after aircraft return.

5)Remove racks when pilot gives permission and meteorologist has cleared area.

6)Inspect discharged flares for duds and misfires.

7)Unload racks and fill out all flare utilization records.

8)Reload flare racks in accordance with next randomization in the numerical order.

9)Unpackage bulk flares to maintain an adequate supply of readily accessible flares.

AIRCRAFT COMMUNICATIONS

1) After a decision to fly has been made, the first duty is to attend the pre-flight briefing for the purpose of learning the intended flight plan.

2) During the flight the communications person is responsible for all communication between the aircraft and the users van.

3) Once an estimated landing time has been set, the last duty is to call the flare technician and alert him to head to the hangar.

4) Attend the flight debriefing.

FORECASTING/NOWCASTING

(performed solely by chief forecaster until 1030, then with nowcaster joining in until 1500-1600, thereafter, run solely by the nowcaster)

Each day

Prepare morning weather briefing
- review weather charts for continuity
- grab sounding data from PIA and PAH for analyses
- Skew T, Log P plots
- thermodynamic/kimematic calculations
- grab North America mandatory-level data for plots on desired levels.
- 1-D cloud model
- retrieve satellite image
- review severe weather files

Lead morning weather briefing

Record weather forecast summary and telephone message

Archive subsequent weather charts and other paper data

Operational days

Monitor weather charts as needed
- review data
- transfer to VAX and obtain data, as per PIA above

Operate nowcasting system
- run hourly surface analyses plots
- retrieve half-hourly 1km satellite images
- monitor weather warning files

Archive IBM data files

Report day's summary at debriefing

Make forecast for morning flight - record on answer machine

DATA MANAGEMENT

1) Organize all data from radar, forecasting, nowcasting, CLASS & aircraft to make analysis easier at end of project.

2) Assist N. Westcott in data entry for PACE 19 8 6 data.

3) Primary personnel for CLASS launches & transfer of this data to VAX.

4) Secondary backup for radar & aircraft communications.

5) Forecaster/Nowcaster assistant including satellite photos, posting of weather maps, organization for 10:00 A.M. weather briefings, etc. (B. Scott, B. Entwistle)

6) Designated photographer for "what the day is like" type photos & possible photos for overlay with radar images (P. Kennedy).

7) Responsible for previous day status verifications at 10:00 A.M. weather briefings.

RADAR ANTENNA CONTROLLER

Before Initiation of Aircraft Mission-

1)Set clock to WWV prior to radar data system turn on.

2)Turn on data system and radar (1 hour is required to fully warm up the radar).

3)Turn on test set; set attenuator to > 100db.

4)If time permits, do receiver and AZ/EL calibrations after 1 hour warmup.

5)According to the logbook entries, prepare the appropriate data tapes for recording.

6)If necessary, begin surveillance scans as soon as practical.

At the Start of an Aircraft Mission-

1)Establish modem link with Hanna City for RATS data acquisition.

2)Set up radar display control in the user van and establish the "standard" PACE configuration (NM units, city map, ZDR and velocity fields displayed, lowest angle image saved, etc.).

3)Enable display of aircraft tracks and enter the appropriate transponder codes as they become known.

During Aircraft Mission-

1)Maintain sector scan limits according to radar meteorologist's advice (maximum volume scan time not to exceed 4 minutes).

2)Ensure maintenance of proper data recording (tapes are mounted, etc.).

3)Keep a log of any apparent radar system abnormalities that may affect data analysis (irregularities in housekeeping data, noise level fluctuations, power interruptions, etc.).

4)See that a time check with the aircraft is done during the return leg.

At End of Operational Day-

1)Calibrate the receiver.

2) Make appropriate entries in the logbook for the recorded data tapes.

3) Perform normal shutdown of the radar.

During non-operational periods-

1) Run quality check program on previously recorded data.

2) Enter the information required in the project data manager's logs.