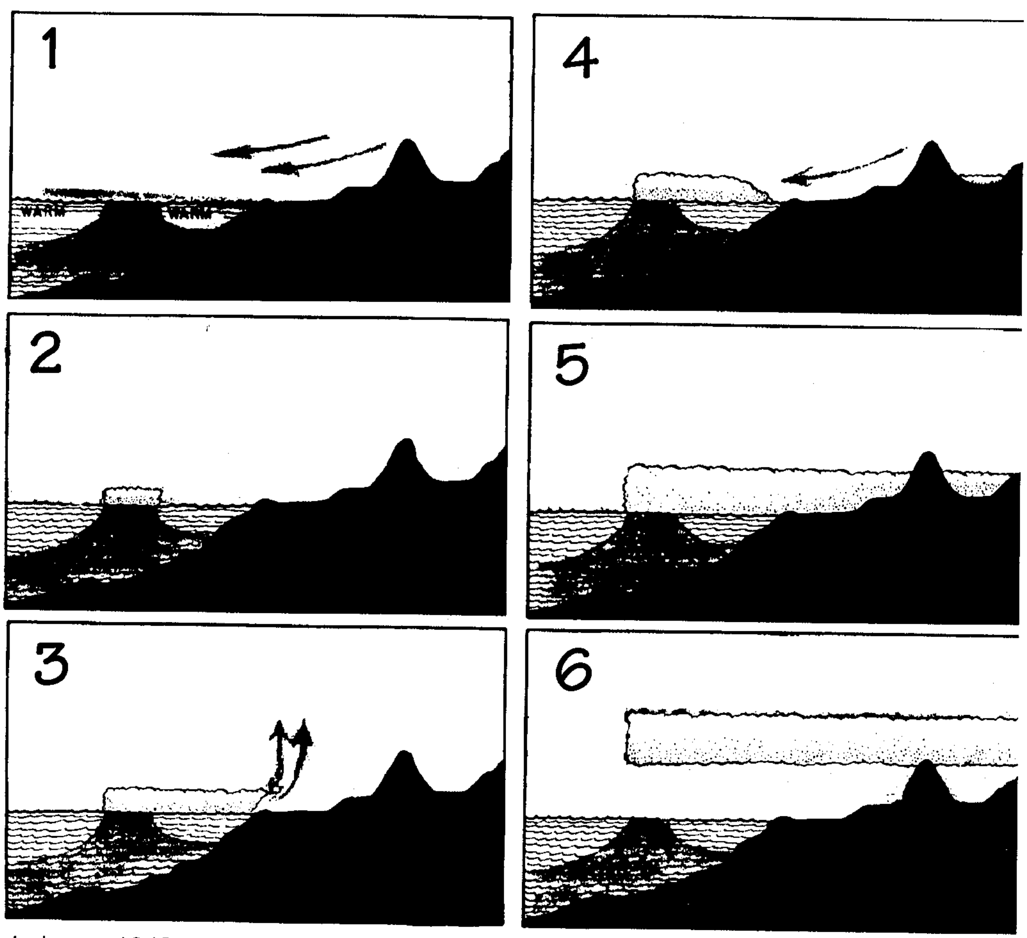
Forecasting Visibility and the Formation and Breakup Times for Fog and Stratus at the San Francisco Air Terminal and Approaches Using LIBS*

*Leipper Inversion Base Statistics

PLANNING AND BACKGROUND

Project note #1 January 28,1998



Leipper, 1948

Forecasting Visibility and the Formation and Breakup Times for Fog and Stratus at the San Francisco Air Terminal and Approaches Using LIBS: PLANNING AND BACKGROUND. Project note #1 January 28,1998

Research Grant Award Number 98-G-004 of the Federal Aviation Admisistration with the Atmospheric Sciences Center of the Desert Research Institute, Reno, Nevada. December 22, 1997 to December 21, 1998

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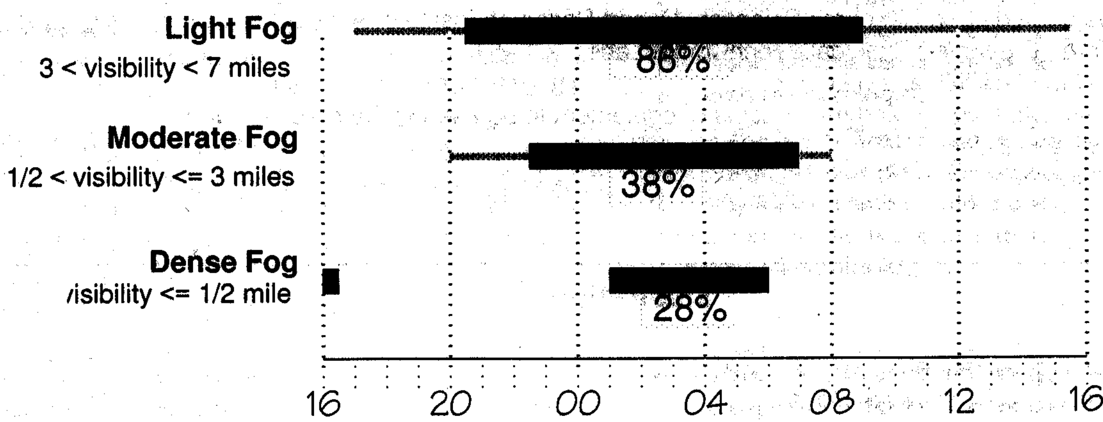
Illustrations

Fog Forecast Worksheet - Phase 1

BI ~ 0, Ta > Tw

Monterey Airport (use only when offshore wind stops)

Dates: ________________ No Fog: ☐ Fog Offshore: ☐



Notes: ______________________________________

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Initials: ________________ Time of Forecast: ________________

Background

On August 11, 1994 an FAA proposal ready for submission and the draft of a publication to be submitted were presented at a meeting arranged in Monterey by William Schram, NOAA Ocean Applications Office. Attendees were representatives of regional agencies engaged in meteorological and oceanographic research. The purpose of the meeting was for Dr. Leipper of TechComm Labs (TCL) to present the LIBS method of west coast fog forecasting. Emphasis was placed on an initial application to the Monterey Airport. David Reynolds, Science Operations Officer (SOO) for the Monterey Forecast Office of NWS, attended the meeting. Copies of the TCL manuscript, which had been prepared for submission to the AMS Journal Weather and Forecasting, were distributed. The manuscript contained a good description of LIBS. After extensive peer reviews it was published in the December 1995 issue of the Journal.

Mr. Reynold's review of the manuscript distributed at the 1994 meeting led to a series of exchanges between him and Dr. Leipper. These exchanges were followed by discussions with the chief forecaster at the SFO (San Francisco) FAA Traffic Control Center, Walter Strach, and a visit and conference there on June 27, 1996. The area of responsibility for the NWS Monterey Forecast Office includes SFO.

At the invitation of Mr. Reynolds, Dr. Leipper presented a seminar on the updated status of LIBS for 16 of the Monterey Office staff members on July 11, 1996. Available at this meeting were copies of a simple LIBS forecaster's manual which TCL had prepared at NWS suggestion. Maux Barnes, Lead Forecaster, offered to tape the talk for limited distribution and educational use. The taping was done on August 8, 1996. A written text (Leipper 1996) has been prepared and it, together with the tape, is being considered by NWS for distribution to other west coast stations. The work and expenses of TCL in this program of collaboration to date have been provided without external funding.

Based upon a survey of the difficulties which Monterey forecasters had in dealing with the critical fog forecasting problem, his knowledge of the LIBS method and his monitoring of the fog related weather at Monterey, Mr. Reynolds decided to set up a testing program for LIBS. TCL is working with him in planning the program. This work led to the preparation of a proposal for a COMET partnership project which has not been funded. Never-the-less, an NWS partner, Daniel Weygand, was recommended by the Lead Forecaster and designated by the Science Operations Officer He and Dr. Leipper began the partnership activity in October 1996.

WEATHER LOG DATA SUMMARY FORM

CHART COLUMN DEFINITIONS

BI = base inversion in meters above MSL
Ta = highest temperature in lowest thousand meters (3281 feet or 557 fathoms)
SST = sea surface temperature
pw = precipitable water
dc = depth of sounding with <= 5kt winds
gws = geostrophic wind speed
gwd = geostrophic wind direction
p 12z = surface pressure at 12Z
d 21z - surface dewpoint at 21 Z
5df = LIBS 5 day forecast code* made at 00 z
5dv = code from observed weather* at 12z
12hf = LIBS 12 hour forecast* made at 00z
prob = LIBS forecast probability
mos = model output statistics forecast
12hv = observed weather* at 12z and adjoining times.
sat = visible satellite at 21z
by = recording meteorologist

*Code for LIBS 5 day fog and stratus forecasts. April 10, 1997

1. FN No fog predicted in the next five days. This is an important forecast, especially in fog season. Although most forecasters have a feeling for it, LIBS gives some numbers to support the hunches.
2. FO A strong offshore geostrophic wind indicating that the initial conditions for fog would develop; that there might be a fog sequence in the coming five days. A clear area is developing along the coast.
3. FS Some fog at sea. The initial conditions for fog are present; BI < 400 m, TI > 0 C May need TI > 5 C. Fog is to be expected in the coming five days.
4. Worksheet for phase 1 of LIBS; BI near zero, TI > 0 C, wind easing.
5. Worksheet for phase 2; BI < 250 m, TI > 0 C, light winds.
6. Worksheet for phase 3; BI 250 to 400 m, TI > 0 C. May get surges, trapped waves, strong southerlies near shore.
7. Worksheet for phase 4; BI > 400 m; low stratus forecast with small probilities of reduced visibility.
8. More elevated stratus decks

The forecasting system

Although many considerations are involved in developing LIBS, the forecasting procedure can be carried out simply and objectively. The forecasts may be improved by the use of judgment based upon experience and knowledge of the system. Following is a brief description of LIBS. This system provides a means for making fog forecasts with detail not known in any other forecasting approach.

As an indication of the practicality of LIBS, Mr. Reynolds writes In a letter dated September 3, 1996:

"LIBS is tailored to the operational forecaster and has been used since the 1940s by Navy forecasters in San Diego. Dr. Leipper's recent publication outlines how forecasters using LIBS can predict on a day by day basis the probability of specific visual ranges each hour at the Monterey Airport. This technique is based on sound scientific principles and years of climatological research.__ We strongly endorse Dr. Leippers research goals__ -".

The Lead Forecaster at Monterey, Maux Barnes, wrote on November 20, 1996:

"__-we have been using your LIBS____ -for the past six months and have found it to be very useful for forecasting 1. The onset of-, 2. The changing of-, and 3. The duration of- Fog and Stratus along the Northern and Central California Coast.

"__-it appears to be the best and most practical method of forecasting fog and stratus that is available at this time.____ -We encourage you to continue your research and to develop more site-specific statistics and verification data."

The scientific basis and the details of the LIBS system are described in two recent publications (Leipper 1994 and 1995). Some 130 references were reviewed and the results of many personal investigations were summarized in preparing these articles. Also, the other approaches to prediction of west coast fog were reviewed and evaluated but these results were not included in the published versions. The text of the talk given to forecasters and the brief forecasters manual for Monterey Airport cover other aspects of LIBS.

LIBS is a conceptual method. A concept, as used here, is a useful opinion or judgment related to west coast fog for which there is considerable evidence but no absolute proof. Further evidence should be accumulated. Some concepts which are useful in LIBS are: that there is a 400 m maximum thickness for a west coast fog or stratus layer; that there exists a sequence of events over days on the west coast from initial clear conditions to fog formation, growth, and then to a stratus deck; the evidence that the 12Z Oakland RAOB represents the BI (height of the base of the inversion) along the coast as far south as Monterey; that the BI and the TI (excess of air temperature in the lower 1000 m over sea surface temperature) are good indices for synoptic changes not traceable by the usual synoptic methods; that there is no subsidence at the coast in the lower 1000 m in fog situations and therefore that adiabatic changes do not affect the TI, and that west coast fog apparently is not advective fog from the open sea.

LIBS has been developed from a forecasting system for San Diego winter fog published by Leipper (1948). Here I had the advice of Dean Blake who was completing his fiftieth year as official Weather Bureau forecaster there. The 1948 forecast method was based upon a sequence of events which occurred regularly over a period of days. Jerome Namais, a well known former chief of long range forecasting for NWS wrote (Personal Communication, 1950) saying he agreed with the physical reasoning involved in explaining the sequence. The same coastal sequence now has been observed to occur on the west coast at times all the way from Baja California to British Columbia. It is the basis of the present LIBS five day forecast.

For input, the LIBS system needs only observations and information readily available. It does not have the very difficult problem of initialization which is common to numerical models.

The LIBS input observations are from coastal stations. Because air flow from land to sea is required to set up the initial conditions for west coast fog formation, fog predictions for offshore areas as well as for specific coastal stations may be prepared from onshore observations- a useful feature.

The LIBS method embraces three scales.

1) Synoptic scale:

At the synoptic scale the position of the north Pacific anticyclone is tracked to recognize the initial conditions leading to a fog sequence, i.e. the inland extension of the high. Before any fog appears, the other related initial conditions are readily recognizable. They are a downslope offshore geostrophic wind, a clear area offshore, and high visibilities with unusually high temperatures (TI > 5 C) along the coast. These conditions guarantee that a strong low inversion favorable to fog formation exists over the sea. Satellite imagery and the BI and **TI** indices are used to verify and quantify these conditions. Since they occur some time (usually days) before any fog is formed, they do not have to be forecast but may be observed.

2) Regional scale:

The initial synoptic conditions place a hot dry air mass over the cool sea in a region which becomes relatively calm. Sea-air interaction in the absence of significant synoptic change in this region then leads to systematic air mass modification. The near surface inversion forms immediately. Under this inversion fog forms and deepens with radiational cooling and mixing. These processes create a mixed layer, i.e. fog creates the mixed layer and not vice versa. The usual time sequence of this development, divided into four phases, is the basis for the five day LIBS forecast. The forecasts may be made for any segment of the west coast where the initial conditions occur.

3) Local scale:

The CWSU forecasters at SFO have previously shown a relation between height of the inversion and stratus breaking time. On the proposed project with the **BI** and **TI** as indices of fog or no fog, a site specific 24 hour forecast will be made utilizing the synoptic climatology for that site and approaches to it. The climatology is obtained by averaging the fog or ceiling height occurrences and probabilities as categorized by ranges of BI, assuming TI is positive and not increasing.

The climatology can be developed and made available to the forecaster as a set of forecast worksheets. The forecast BI determines which worksheet to use, if TI is favorable. The worksheet provides the basic hourly forecast of fog visual range or ceiling height and their probabilities for the existing synoptic situation indicated by the forecast BI range. The trends of the diurnal cycles as calculated for these worksheets may be used at any time to predict within minutes the specific formation or breakup times for fog and stratus. A figure showing sample worksheets for fog at the Monterey Airport is attached. Two recent comprehensive studies, (Bergman and Salby 1997) and (Krzysztofowicz and Sigrest 1997) lend strong support to this use of local synoptic climatology in cloud and moisture prediction.

Sample worksheet

The sample worksheets reproduced on page (iv) and with verification on page 8 are an example of the ones developed for the Monterey Airport. The worksheets illustrate the different fog phases at MRY. The horizontal bars represent the recommended forecasts, and their probabilities are indicated. It is apparent that a major change from phase to phase in the case of MRY is in the probabilities of fog occurrence. A curve connecting the termination points of the bars for dense, moderate and light fog gives the climatological trend for dissipation of the fog. Its extension after calibration using the latest observed values available gives the breakup time. These times could be read in minutes.

Project Summary

Additional weather information and improved forecasting capability are needed to aid in more effectively managing the extensive air traffic at the San Francisco International Airport (SFO) and its approaches. The objective of this proposed research is to provide for improved site-specific forecasts of fog and stratus at these locations. These forecasts will be for low clouds, and light, moderate, and dense fog with the probability of occurrence for each of them. Emphasis will be upon predicting the exact breakup time of stratus decks. The forecast tools will be developed for SFO and approaches as described for Monterey in recent publications about LIBS and built upon aids now in use experimentally there.

The key west coastal large scale event which brings about the initial conditions for a fog-stratus sequence is the extension inland of the Pacific anticyclone. There is then a coastal segment where flow of subsided air adiabatically down the slopes of the coastal mountain range gives hot dry offshore winds such as the Santa Anas. Over the cool ocean a surface or near surface inversion which may be strong enough (5 C) to lead to fog formation is observed. As the offshore winds ease, a regional scale sea-air interaction takes place systematically giving a shallow fog which gradually deepens and rises to become stratus. For the local scale the topographic influences upon SFO and the synoptic climatology must be taken into account as has been done for Monterey Airport but using the greatly increased air and ground data resources for the SFO area. Levels to 1200 m will be added. Test products for SFO would be available within the first year.

The desired SFO forecast for any given time will be read off the appropriate 24 hour worksheet to be developed in this research. To obtain forecasts of exact formation or breakup times of fog or stratus, the categorized climatological rates of change in visibility or ceiling height will be adjusted according to the latest available observations and the trend extended to the clearing level where the time within minutes will be read off.

New worksheet features for SFO and approaches

The worksheets for SFO and approaches will be unique because of the protected location and complex environs of the airport. The categorization of the climatology as in LIBS will do much to account for these effects under different synoptic situations. The fogs which occur on the open coast with BI below 300 m will seldom be observed at SFO. The statistical categorizations used for Monterey Airport will be altered for SFO to cover inversions to 1200 m (3937 feet) and the categorization for statistics above 400 m will be by shallower layers of altitude, 200 m or less. They will include the probabilities of occurrence and the synoptic climatology for stratus variables such as ceiling heights, cloud thickness, and times when coverage becomes broken, scattered and clear. They will thus represent the approaches to the airport as well as the site -specific terminal. Hopefully aircraft data will become more readily available to allow climatologies of the approach zones. The research will utilize new computer programs and capabilities as well as internet resources.

Goals and objectives

1) Goals

To create station visibility and low ceiling forecasting worksheets for SFO and approaches. The worksheets will provide means of predicting stratus breakup times within minutes.

To extend LIBS to include more complete stratus forecasting

To work with forecasters and the use of real-time data.

To consider converting portions of LIBS, which is now a conceptual model, to a numerical approach if this seems desirable.

2) General guidelines

The LIBS methods will be extended to predict the presence of stratus, the heights of stratus ceilings and tops, and the slant visibility through stratus. It is concluded that the most needed visibility and stratus forecasts at SFO are continuous values through the day, especially during the evening period of exact formation times and during the exact breakup times on the following day. For this reason, it is the intention here to give highest priority in the research to preparation of the worksheets for SFO and approaches. The recent efforts by agencies such as NOAA to make large amounts of environmental data readily available, the new internet resources, the present PC workstation storage and data management capabilities, and the new software development environments offer major advantages for research such as proposed here.

The research for SFO would use the SFO hourlies with the Oakland RAOBS. These RAOBs were also used for the MRY LIBS forecasts. Neighboring SODAR observations would also be used. The programs to be developed for data analysis would be useful to other researchers using similar data bases. Software developments will be undertaken as needed. Related developments by others will be monitored for possible use.

One source of stratus is a fog that has achieved the usual maximum depth of 400 m at sea and lifted off the surface. The LIBS sequence may be extended to provide forecasts of cloud ceilings, tops and slant visibilities after this lifting occurs. This study will be approached by tabulating averages of the stratus variables for the BI categories of 400 to 600 m, >600 to 800 m, >800 to 1000 m and >1000 to 1200 m. These are the altitudes at which stratus problems are most severe for aviation at SFO. Whereas many stratus projects depend upon surface temperature and dew point to determine the lifting condensation level and ceiling, this effort will emphasize the changes in ceiling by referring to the cloud tops, utilizing the height of the inversion base and the concept of a mean average stratus thickness of 400 m for night time.

Real time fog and stratus weather will be followed.

Any forecasting process depends critically upon the people who implement it. The LIBS methods may be used as a simple objective forecasting tool. However, the proposed methods have several unique attributes that may be leveraged to positively impact staff morale and participation. Local forecasters should be involved in the process of refining and extending the method to their particular station.

The purpose of project personnel being involved in present weather considerations is to evaluate the significance of forecasting using the LIBS method , the veracity of the forecasts, the ability of on site staff to utilize the method and its concepts, and the impact that implementation of LIBS based forecasting will have on operations.

Later elements of the approaches

In considering the relationship to long term goals, there will be a set of forecast worksheets for SFO as checkpoints for intermediate success. Continuing work will emphasize the increased use of remote sensing. An early version of these procedures for SFO, including worksheets for stratus forecasting, would be completed in the first year.

In the second year the major effort would be in the extension of the LIBS worksheets to include more refined prediction of ceiling heights, cloud tops, formation and breaking times, and slant visibilities for stratus. Another emphasis would be in the refinement of the sequence prediction procedures for SFO. The five day forecasts would be tested.

Specific steps to be taken

1) Prepare letters and semiannual reports of project progress. Prepare other reports or articles as appropriate.

2) Create SFO station forecasting worksheets.

3) Identify any additional resources useful in this research.

4) Identify data publishers, methods, and costs of acquisition of basic data required

5) Create a ten or more year historical library of pertinent data to facilitate analyses and climatological studies.

6) Develop procedures and algorithms to:

(i) Transfer and convert data as necessary for analysis.

(ii) Design and create databases to facilitate LIBS analyses and studies.

(iii) Classify hourly data into visibility events.

The hourly data needs to be scanned to find reduced visibility observations. A series of consecutive hourly observations of reduced visibility must be determined for length of restricted visibility and history of visibility restriction within this period. Other parameters of the event will be determined.

(iv) Determine inversion base from RAOBS.

Each atmospheric sounding must be analyzed to determine the height of the inversion base, the temperature index, and other selected parameters useful to the LIBS method.

(v) Create fog day database.

A fog day is defined as the twenty-four hour period of time starting at 4 p.m. local time. A database will be created with one record for each day for which observations are available. This record will contain fields for inversion base height class, number of hours for visibility in each of the visibility and low ceiling classes, and similar data designed to facilitate the creation of LIBS worksheets.

(vi) Find visibility and low ceiling event sequences matching the LIBS sequence.

Once such events are classified, the list of these events will be analyzed to find sequences that fit the basic pattern defined by the LIBS model. This will provide a sample set for forecast verification studies and will also provide statistics to help quantify and define the share of the visibility problem that LIBS methods address. This process will need to account for diurnal patterns in the list of visibility events and for short gaps and similar phenomena.

(vii) Match inversion base data to observed LIBS sequences.

The result here will be a series of complete data sets for evaluating LIBS forecasts against actual events.

(viii) Calculate worksheet data summaries.

Once LIBS pertinent data sets have been developed, they can be statistically analyzed to determine the values needed to generate forecasting worksheets

(ix) Determine availability, limitations, and costs associated with the collection, preparation, and publication of enhanced LIBS indices data, including RAOBS, temperature indices, winds and moisture aloft, and BI.

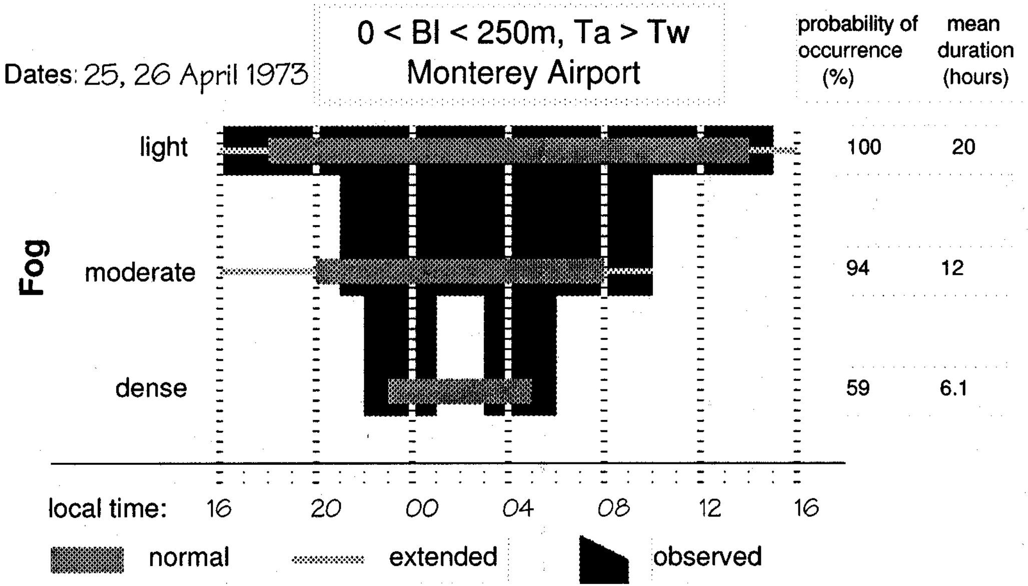
The data problem

The rapid expansion of the internet, the drastic reduction in costs for online storage and processing capability, the development of cross platform development tools and methods, and the increasing availability of low or no cost tools and platforms has created unique opportunities that meteorological data stores are only beginning to utilize. Current observations are needed for forecasting and hostorical records for accurate descriptions of event behaviors as well as investigation and research.

At the start of this project, public access to current observations was unreliable, data from the recent past unavailable, and long term histories were in a mishmash of formats from a variety of sources on a variety of media. There is work in progress to resolve these issues and much progress is being made.

It is envisioned that investigations, such as those required for LIBS type phenomena analysis, can be achieved using commonly available internet access tools to query a coherent database of meteorological data that is updated with current observations. It is hoped that the situation will approach that currently implemented for commercial activities such as data mining to investigate sales trends and demographics. On line transaction processing, platform independent data access, large (terrabyte) databases, distributed processing, and interactive investigation are being done to support trade and commerce - why not to support meteorological research?

Fog Forecast Worksheet



The broader context

Relationship to the longer term

LIBS research as proposed here will provide better understanding of stratus forecasting problems at other west coast terminals, will contribute to the knowledge of cloud physics, to global climatology as affected by cloud cover, toward solving weather problems related to topography, and to knowledge of land-sea-air interaction.

The proposed research will provide insight into a number of problems now being considered and requiring further investigation. Among these are improved prediction of inversion height, further knowledge of fog and stratus character and behavior and prediction of fog and low ceilings for offshore areas.

A critical element in LIBS is the prediction of the range of inversion height. Although the LIBS sequence contributes significantly to the ability to predict it, improved methods will be sought, continuing the cooperation with duty forecasters.

Satellite imagery showing cloud cover off the entire California coast is a common sight on public weather news shows. Such imagery is readily available and can be used to indicate conditions which might lead to the development of fog and stratus. The more complete set of conditions, including information from other sources, is described in the Leipper Inversion Base Statistics method. All of this information can be used in conjunction with local climatological data to formulate specific hourly visibility forecasts.

The LIBS method is designed to bring out areas where further research is needed and to allow the incorporation of new research results as they are obtained. Verifications and verification statistics will make use of available programs and capabilities. Allowance will be made for observation sets not having complete hourly records.

Relationship to present state of knowledge

LIBS follows the recent guidelines of the FAA Air Weather Research (AWR) Product Development Team for Ceiling and Visibility. The LIBS system also already incorporates many of the desirable features sought in the recent report of the U. S. Weather Research Program (USWRP) Prospectus Development Team for Coastal Meteorology and Oceanography. These include distance scales of 0 to 50 km; time scales of 0 to 24 hours; site specificity; coastal orography and ocean influence considerations; low cost; being ready to go; and simple to introduce.

The proposed LIBS research seems unique but complementary to other visibility research such as that in NWS, NRL, MIT, SIO, UCSD, SDSU, San Jose State, the University of Washington, and Penn State. There is no other research known to us, other than the Penn State project and MOS, which attempts to predict the occurrence of no fog, dense fog, moderate fog, and light fog at a given location. Neither Penn State nor MOS nor any other project predict probabilities nor give the time of formation and dissipation as does LIBS. Most others rather predict the condition at only given times, which is not as useful.

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1) Education

Hon. D. Sc., 1968, Wittenberg University

Ph.D. 1950, Scripps Institution of Oceanography, University of California

M.A. 1939, The Ohio State University, mathematics

B.S. 1937, Wittenberg University, mathematics and education

Certificates in Meteorology. 1943. UCLA and the University of Chicago, 1943-1944.

2) Professional interests

Dr. Leipper has experience as a weather forecaster and research officer, Captain, AAF, Alaska and the Aleutian Islands 1943-1944; Researrch and teaching assistant, Scripps Institution of Oceanography, University of California, 1946-1949; Professor of Oceanography and Meteorology, Texas A&M, 1949 to 1968 (Department head 1949 to 1964) and at the Naval Postgraduate School, 1968 to 1980 (Department chairman 1968 to 1980), then part time until 1990; Independent research 1990 to 1996; Research Scientist, Desert Research Institute, 1996 - .

He is. author of some 90 publications and reports on oceanography and marine meteorology. including currents in the Gulf of Mexico, hurricane-ocean interaction, ocean temperature variations, and forecasting of west coast fog and stratus.

3) Selected recent publications and reports:

Leipper, D. F. (1998) ; Hot spells and their role in forecasting weather events on the U. S. west coast. Preprints of the AMS Second Conference on Atmospheric and Oceanic prediction and processes, 11-16 January 1998, Phoenix, AZ. 6 pages.

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Other publications in hurricane-ocean interaction, sea-air interaction and education in oceanography.

Bryan R Leipper, Principal, TechComm Labs

1) Education

1974 B.S, physics, California Polytechnic State University

1982 M.S. science education, Eastern Connecticut State University.

2) Experience

President, TechComm Labs since 1978; Partner, Leipper Management Group since 1995

Four years experience in public school science education

Four years experience as programmer/analyst at nationwide medical service firm

Four years in association with Dale F. Leipper working on west coast fog and stratus.

Author and columnist: amateur radio curriculum, instructor and student materials; calculating satellite orbits with simple computer systems; newspaper small business column; newsletters; presentation materials.

Software system design and implementation: multi computer jobs management system, contact database, insurance planning, geographic properties and mapping, custom business applications.

Nearby facilities and resources

Desert Research Institute and its meteorological library (Contacts: Gary Hanneman, librarian and computer specialist; Darko Koracin, boundary layer modeler, Steven Chai, meteorologist; James Hudson, atmospheric physicist; Melanie A. Wetzel, associate research professor, remote sensing; and Harold Klieforth, research meteorologist.)

Western Regional Climate Center (Contacts: Richard Reinhardt, director ;Kelly Redmond, deputy director; Dorothy Miller, climate data manager; Greg McCurdy, climate applications programmer; and Jim Ashby, assistant climatologist.)

National Weather Service Forecast Office (Contact:Steve Brown, meteorologist in charge, Mary M. Cairns, science and operations officer, and Roger Lamoni, meteorologist)

The University of Nevada at Reno, Dr. Ken Hunter, Dean of the Graduate School and Director of Research; Dr. John Kleppe, Head of the Department of Electrical Engineering).

Reno Tahoe Airport, Stead Airport, Gallon Naval Air Base

Active AMS chapter, and a local amateur radio group involved in EME, telemetry, packet and similar technologies.

Available facilities and major items of equipment to be used in the proposed work.

TechComm Labs is a Nevada Registered trademark of the Leipper Management Group. The resources at this facility are designed to facilitate effectiveness in the areas of information systems and education. The capabilities are especially appropriate to data intensive research such as is required for refinement and application of the LIBS method for fog forecasting.

Office facilities

- three separate offices in two structures equipped with telephone and workstations in a home environment

Computers and Hardware

- a network of Intel architecture, IBM compatible computers connected via coax and twisted pair
- high speed facsimile and data modems on most computers
- CD Rom with write once capability
- Tape backup: 8mm
- Online storage of more than 12 Gb, 3 Gb on most machines
- Hewlett Packard Laserjet, Deskjet, C Itoh, and Epson printers
- Uninterruptable Power Supplies for the most systems

Software

- OS/2 as primary and Linux (Unix variant) as secondary operating environments supporting most widely available software for DOS, Windows, OS/2, and Unix platforms. NT small office and Windows 95 available on test systems
- Networking software includes Lantastic from Artisoft, IBM Lan
- Database software includes DB2/2, Paradox for both DOS and Windows, and others

►Software development environments include Java, C, C++, Rexx, PAL, OPAL supported by IBM, Borland and Watcomm

►Accounting with Quicken, TurboTax and custom database systems

►Spreadsheet and presentation includes Lotus 123 and Freelance Graphics, Corel Draw and Ventura Publisher

►Facsimile supported by Faxworks from Global Village

►Terminal Communications supported by PM Comm

►Internet Access supported by IBM Warp Internet Access Kit

►Word Processing includes DeScribe, IBM Works, AmiPro, Sprint, Wordstar and others

►Tape backup software includes DualStor and EZTape (for QIC), Sytos, Novaback, MKS (for 8mm), and Gnutar.

►Utility software from IBM's Developer Connection, Mortice Kern Systems, and various other sources

Communications

►three telephone lines

►telephone management for automatic facsimile switching on two primary lines

►telephone mailbox and annunciator system

►CompuServe and Advantis Internet online services via dial up modem

►stand alone facsimile plus internal modems

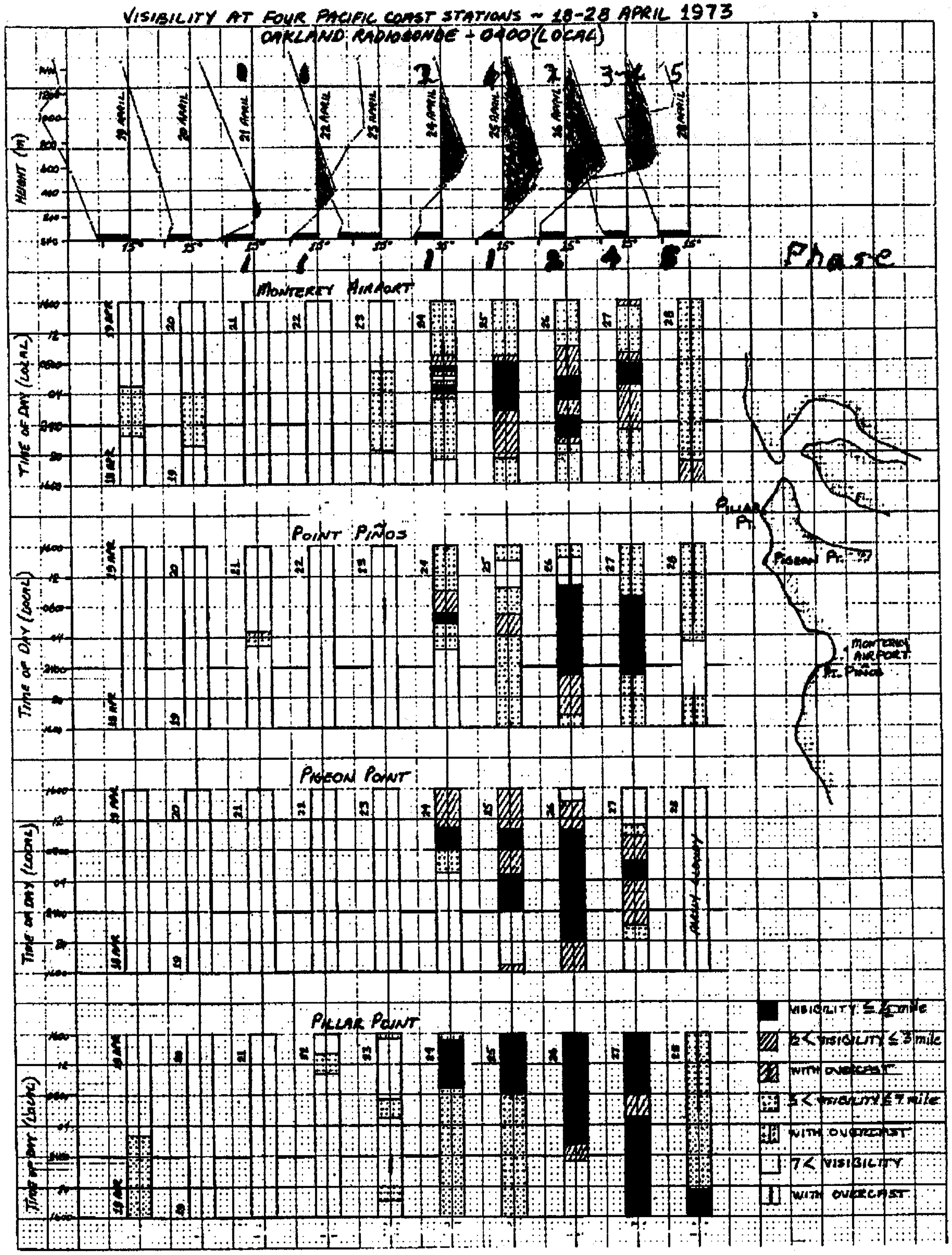
References

Extensive lists of references are included in Leipper 1994 and 1995 above. Also see Leipper biographical sketch.

1997: Bergman, J. W. and M. L. Salby: Diurnal variations of cloud cover and their relationship to climatological conditions. *Journal of Climate*, Vol. 9, Page 2802

1997: Krzysztofowicz, R. and A. A. Sigrest. Local climatic guidance for probabilistic quantitatie precipitation forecasting. *Mon. Wea. Rev.* 125 p 305.

Circa 1975 analysis of visibility and Oakland sounding data along the central California coast.



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