UCID-16565

This is an informal report intended primarily for internal or limited external distribution. The opinions and conclusions stated are those of the author and may or may not be those of the laboratory.

LAWRENCE LIVERMORE LABORATORY

University of California/Livermore, California

FINAL REPORT ON ENVIRONMENTAL DEFINITION PROGRAM

For period ending June 30, 1974.

Joseph B. Knox

James E. Lovill

July 25, 1974

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

Prepared for Defense Nuclear Agency Headquarters, Washington, DC 20305
under contract DNA NWE Subtask N99QXAA 128 Cloud Phenomenology,
Work Unit 26 Hydrometeor Environment
Prepared for U.S. Atomic Energy Commission under contract no. W-7405-Eng-48

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

FINAL REPORT ON ENVIRONMENTAL DEFINITION PROGRAM

For period ending June 30, 1974.

Joseph B. Knox
James E. Lovill

Lawrence Livermore Laboratory, University of California,
Livermore, California 94550

I. Description of the Satellite Remote Sensing Program at the
Lawrence Livermore Laboratory

Satellite monitoring of the stratosphere and troposphere is providing input for the LLL studies in wave dynamics, transport, and kinetics problems, ice cloud monitoring, radiation balance, and long-term climate changes.

Dependent atmospheric variables have been measured over data sparse regions of the world (the Atlantic and Pacific Oceans, most of the Southern Hemisphere and the Equatorial Regions). High-resolution data is gathered over major urban areas and in locations where large natural and man-produced atmospheric modifications may occur. These data are collected on a daily basis from both near-earth, polar orbiting, and far-earth, sun-synchronous satellites. These satellites provide thousands of vertical profiles each day of various atmospheric parameters - temperature, water vapor, ozone, global and regional albedo, (e.g., ice and liquid content clouds) and various discrete radiational emission spectra.

In other areas of interest world-wide volcanic activity is monitored. (This was begun in a previous LLL report). The resulting radiational changes and solid particle influx into the atmosphere may be inferred in this manner. We also monitor large energy and solid particle inputs to the atmosphere from such sources as the world-wide oil field gas flaring and recent large fires on the Argentinan Pampas. We are utilizing our satellite technology to determine variations in ozone over past nuclear explosions.

We are actively involved in satellite environmental monitoring programs using NASA, NOAA, and DMSP satellites, and were requested to advise the third Skylab astronaut team on techniques to acquire energy spectra over several regions of the earth.

Satellite studies in all of these areas are needed if we are going to address ourselves to the many pressing problems in climatology and meteorology on a global or regional scale. Satellite sensor technology is being developed to the extent that various atmospheric parameters may be determined to a high degree of accuracy. This accuracy continues to improve and LLL is providing advance direction for these improvements.

These satellite data and analyses will provide unique global climatic data and parameters necessary for the development of a spectrum of models: for the study of tropospheric-stratospheric mechanisms; for inclusion into climatic models; as well as for the daily atmospheric analysis problems that require fast problem-solving turnaround (e.g., monitoring of aircraft produced ice clouds and natural ice cloud variability).

II. Cloud Phenomenology Objectives

The ice cloud phenomenology program at the Lawrence Livermore Laboratory was initiated in mid-1973 to devise methods of describing the distributions of cirrus and their physical properties, intercorrelation techniques for cirrus cloud measurements, and to evaluate techniques for estimating ice component distributions in the upper portions of cumulus congestus.

This program was divided into two separate tasks:

1. Acquiring high resolution, infrared and visible wavelength satellite data:
 - a. For climatological purposes.
 - b. For individual mission R/V studies.
2. Analysis of these data would determine:
 - a. Whether cloud were liquid or ice.
 - b. If ice, the amount both temporally and spacially.
 - c. Relative thickness of cloud (by inferred opacity).

This report discusses the satellite data acquired in Part 1 (above). Discussion is also given to the building of computer software to interpret these satellite data in a concise and quantitative manner which began early in January 1974. This software (once completed) will give LLL the ability to readout any analog or digital satellite tape received from NASA, USAF, or NOAA. Codes are being developed at LLL to analyze these data, such that a complete computer identification of the problem may be obtained within seconds in a multi-parameter, multi-level presentation on a scale from regional to global.

III. Satellite Data and Analysis

DMSP visible and infrared data were obtained in a digital format for all Environmental Definition Flights when G-Division was notified by MRI. Most of these data are on tape. Several of the areas of interest could best be covered at the time by positive hardcopy.

The satellite data from two of these flights were presented at an MRI briefing in February. An additional analysis was sent to DNA in April. With only one exception (see Appendix for "Analysis of High-Resolution Infrared Ice and Water Clouds") the rest of the flights were to be analyzed using the satellite digital tape and an objective computer approach. This approach involved the building of software which could display a numerically coded grey-scale of ice cloud extent over any area from the meso- to the planetary-scale. These efforts are continuing in several programmatic areas.

IV. Future Studies

The present studies being conducted by the various agencies involved in the Environmental Definition Program are providing data that are distinctly necessary for final conclusions relative to erosion caused by various hydrometeors. In order that a comprehensive analysis of the ice erosion may be completed, the following tasks are entertained.

1. Quantitative Computer Analyses of Cirrus and Cumulus Congestus

Using High-Resolution Satellite Data

The ice cloud study would be divided into two areas of study:

- 1) Large-scale geographical approach, and 2) meso-scale approach.

The large-scale investigation would consist of collecting, and in a quantitative process, analyzing satellite data for the various seasons over a period of one year in order to establish a climatological base of ice cloud coverage over the Soviet Union. This concept is different from qualitative analyses of cloud pictures or a statistical analysis of published Soviet meteorological data. This approach utilizes techniques developed especially for the analysis of digital satellite data. These computer routines have been built to utilize multi-spectral data in spline function structured schemes. The computer memory capacity of our facility is capable of processing the massive data amounts which would be required under this approach. The final computer output would be presented in a numerical format where cloud gray shades would be correlated with numerical values. The data would finally be presented in daily, weekly, monthly, and seasonal maps and graphs of frequency of occurrence at various latitudes.

The meso-scale study, utilizing the same quantitative computer techniques discussed above would employ high-resolution satellite data to study in great detail the ice cloud morphology in the reentry vehicle environment.

2. Future Satellite Sensors

A comprehensive study should be initiated to determine the satellite sensors that will be required to measure liquid and ice cloud characteristics, and to do so on a global as well as specified region basis. The various parameters these sensors would measure are: 1) The particle number density [+ particle size],

and 2) the optical thickness [+ height of top]. The following sensor design and wavelength locations have been arrived at after careful and lengthy consultation with representatives of NASA, the University of California, and NCAR. The conclusions represent the most current, but not necessarily the final, best techniques.

The initial sensor design should be such that areal resolution is as small as ~ 1 km. The sensors should be placed on a satellite in polar orbit, but later efforts should be directed toward placing the sensor packages onboard future geostationary satellites as well, in order that continuous surveillance may be obtained.

The number density can best be measured at wavelengths of approximately 1140 nm. The particle size may be determined at wavelengths near 5×10^4 nm.

The optical thickness can best be determined by utilizing wavelengths of $\sim 1.1 \times 10^4$ nm and 10^6 nm. This technique would determine the temperature of the cloud top, and then the brightness, to infer a temperature gradient, which allows an additional piece of information. The 760 nm wavelength could be useful in determining the cloud top height to an accuracy of ~ 100 m.

Our present satellites do not have these capabilities. The technology is available to build sensors with the above specifications. Sensors at these recommended wavelengths must be flown on aircraft and "breadboarded" before satellite sensor design is finalized. Plans of this type have evolved frequently in the past several years in the space program. This is not an immensely more difficult task than those attempted in the past. There are many areas of the atmospheric sciences in which data of the type discussed above could be invaluable

and for the final analysis of ice cloud structure, this is certainly true as well.

3. High Altitude Ice Clouds

High altitude ice clouds [Noctilucent Clouds (NLC) and Mother-of-Pearl Clouds (MPC)] may have an effect upon R/Vs. Simply because these clouds are not frequently seen is no reason to suspect they do not exist. In fact, considerable recent evidence supports the point that from 50-65°N NLC (and MPC to a lesser extent) may frequently exist near 80 km. On occasion these ice clouds (with estimated particle of radius .05 to 1 μm) may have an areal extent in excess of 3 million km^2 . The greatly amplified radiation in the 400-1100 nm band of the defense meteorological satellites has the capability of measuring not only cirrus type clouds but possible NLC and MPC as well. From the evidence gathered to date, there have been no actual measurements of the particle density in the NLC. There is a subjective feeling that the particle density could, in many cases, approach (to within better than an order of magnitude) that of cirrus ice particle density--this conclusion appears supported by the fact that the NLC is frequently as opaque as cirrus. A particular advantage to observing the NLC from space is that there is considerably less atmospheric attenuation, than if viewed from the surface. Therefore, the cloud contrast is increased considerable. In addition, the several angles (that the satellite permits) will allow more accurate estimates of NLC particles size and particle size distribution. A study to determine the high-latitude spatial and temporal distribution might be of considerable future benefit if the particle density and/or size can be shown to be sufficient to produce R/V erosion.

Appendix ASatellite Data Analysis

These satellite data show the evolution of a 5-day diffused expanding region of atmosphere in which ice and water clouds are measured separately by satellite analysis of high-resolution, 400-1100nm and 7900-12700 nm wavelengths. The period covered was from March 31 through April 4, 1974. The fifth, and final day analysis, consisted of a 20 x 20 grid at one degree intervals. The micro-structure of each one degree square was further analyzed. The 500 meter resolution of the sensor will permit 1.97×10^7 data points to be analyzed on the final day over the diffused region.

The object of this study was to determine the horizontal extent of cirrus (ice) clouds in the upper portions of large cumulus or convective cells. When the two sets of wavelengths are compared and the infrared weighted properly, the ice clouds coverage can be determined. In the satellite data sets analyzed below it is readily seen that the contribution from ice attributed to cumulus congestus is minimal, at least in this case study. (Upper tropospheric flow was zonal over the lower and mid-latitudes studied).

March 31, 1974

Satellite Aereal Coverage = $4.9 \times 10^4 \text{ km}^2$

51% total cloud cover [ice and liquid water]

42% liquid water clouds [$\Rightarrow$ low and middle clouds]

9% ice clouds [$\Rightarrow$ sufficient vertical development to reach above freezing level; or cirrus cloud]

90% of total cloud consisted of closed cells [this would imply that no more than 8% of the area could be covered by cumulonimbus]

April 1, 1974

Satellite Areal Coverage = $3.1 \times 10^5 \text{ km}^2$

14.2% total cloud cover

13.7% liquid water clouds

0.5% ice clouds

70% of total cloud consisted of closed cells [this would imply that no more than 0.35% of the area could be covered by cumulonimbus]

April 2, 1974

Satellite Areal Coverage = $1.2 \times 10^6 \text{ km}^2$

20.4% total cloud cover

20.4% liquid water clouds

0.0% ice clouds

20% of total cloud consisted of closed cells [no cumulonimbus]

April 3, 1974

Satellite Areal Coverage = $2.4 \times 10^6 \text{ km}^2$

65.7% total cloud cover

65.7% liquid water clouds

0.0% ice clouds

70% of total cloud consisted of closed cells [no cumulonimbus]

April 4, 1974

Satellite Areal Coverage = $4.9 \times 10^6 \text{ km}^2$

41.1% total cloud cover

39.8% liquid water cloud

1.3% ice cloud

85% of total cloud consisted of closed cells [no more than

1.1% of area could be covered by cumulonimbus]

Appendix BCloud Modeling

Under the support of the Environmental Definition Program, our one- and two-dimensional, time-dependent models of convective clouds have been modified to include output of data on the amount of condensed water of various types (droplets, drops, ice crystals, frozen drops) as functions of time and height. We are also able to calculate the net upward flux of moisture in convective clouds. Results of these types have been supplied to DNA with our periodic reports.

While work was begun on developing a numerical model of cirrus clouds, there are no results to report on that currently suspended project. If such a model is developed, it will be necessary to have measurement data on which to base assumptions and for validation.

Distribution

LLL Internal

B. C. Groseclose
J. E. Lovill
C. R. Molenkamp
R. C. Orphan
H. L. Reynolds
G-Division Files (3)
TID Files, L-9 (5)

External

Mr. Morton J. Rubenstein
Office Deputy Director
Science and Technology
Defense Nuclear Agency
Washington, DC 20305

NOTICE

"This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately-owned rights."