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6-23-76
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STATUS REPORT: LAWRENCE LIVERMORE
LABORATORY WIND ENERGY STUDIES

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June 1976

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Prepared for U.S. Energy Research & Development Administration under contract No. W-7405-Eng-48.

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ABSTRACT

Numerical model calculations of three-dimensional regional wind fields oriented toward identifying the location, intensity and extent of wind energy-rich areas on Oahu are reported. The use of these calculations in planning a field data-collection program to study areas of expected high wind energy is described. Criteria for the selection of wind-energy subregions of primary interest are discussed.

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*Work performed under the auspices of the United States Energy Research and Development Administration, Division of Solar Energy, under Contract No. W-7405-Eng-48.

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1. INTRODUCTION

In September 1975, the LLL was requested by the Wind Energy Conversion Branch (DSE, ERDA) to develop a regional wind power assessment capability for the national wind energy program. The specific objective of this effort is to develop, verify, and apply regional methods to document the energy of time averaged wind-fields* suitable for "tapping" the energy of the wind by large wind turbine generators (WTG). The study team has selected the island of Oahu as an initial test-bed for techniques development and to demonstrate initial applications to the siting of WTG for electric generation purposes and/or for use by the Hawaiian Electric Company in selecting sites for large prototype WTG. During a multi-agency planning session in May 1976, it was suggested that a preliminary report of our findings to date was desirable. It is our purpose to satisfy this stated need with the present report. Particular interest was expressed in the regional wind flow-fields calculated from historical wind information for the most frequent winds during July (about ten years of data) for nine stations obtained from the NCDC Asheville, North Carolina. These calculations, prepared as an early guide for field exercises in July-August 1976 by the LLL wind power team on Oahu, constitute first-order estimates as to the location, intensity, and extent of the wind energy-rich regions of Oahu. We intend to utilize these results as wind prospecting guides for conventional and long-path remote sensing measurements during our July-August field program. During this period, we plan and

*Power spectrum studies (Fitzgerald, 1976, JAM) of the convective boundary layer show that most of the kinetic energy (of the wind) is in scales having characteristic times greater than 5 to 20 minutes. Such averaging times are properly used in regional wind studies oriented toward siting problems (as distinguished from design problems).

expect to gather much more complete data which will be analyzed by our regional diagnostic flow models and compared to our planning calculations. Since the results and findings of the July-August study will not be available for several months, it is now of some importance, as previously mentioned, to document these early findings.

The LLL regional wind power studies project has three elements:

- (1) The adaption and use of existing ERDA-developed diagnostic regional flow models to the calculation of fields of motion over three dimensional complex terrain appropriate for the siting of large WTG.
- (2) The application of both conventional and portable Laser Scintillation Anemometer (LSA) measurement systems to test and verify the regional flow classification methods;
- (3) The development and use of regional flow classification methods, in particular, principal component analysis, such that regional wind potential can be economically assessed from long periods of meteorological data records using these relatively advanced techniques.

The present status report will, however, concentrate on the presentation of and interpretation of the regional flow calculations prepared from the historical data previously described.

2. PLANNING CALCULATIONS OF THE REGIONAL FLOW OVER OAHU

The regional flow model used in these studies is MATHEW,^[1] which has been under development and partial verification at the Idaho National Engineering Laboratory and at the Savannah River Plant (SRP) for tracer studies.

The meteorological station locations on Oahu are shown in Figure 1, in which the most frequent wind direction and speed has been plotted for the month of July (corresponding to the peak of the trade wind season). The winds of Oahu have been adjusted to 50 meters above terrain by means of the power law relation with a value of $p = .15$. Figure 2 shows the topography (150 meter contours) utilized in the study. The calculations for the whole island use a horizontal mesh size of 1000 meters and a vertical mesh size of 150m. The calculated flowlines and isotachs of the flow 150m above terrain are shown in Figure 3. Of special interest are the wind energy-rich subregions near Koko Head (15 m/s), Kahuku Point (14 m/s), and Mauna Kapu (about 12 m/s). Stronger flows of lesser extent, channeling the flow through the ridges, are indicated at selected passes. An extensive area of winds in excess of 10 m/s is indicated to the west of Kaneohe Bay.

It is most pertinent to ascertain the stability of the locations and the character of these wind energy-rich subregions with increasing model resolution (decreasing horizontal and/or vertical mesh size). The wind maxima should ideally not change in location and strength in a converging solution; but, on the other hand, it is clear that increasing resolution in the lower boundary conditions may cause the maxima to legitimately shift due to improved lower boundary condition definition. It is most pertinent to gain experience in regard to these questions, holding the meteorological input data fixed.

Figures 4, 5, and 6 show the regional flow and isotachs 150m above terrain (50 meters for Fig. 7) for the most frequent winds in July using Δx , Δy equal to 500 meters, which leads to improved resolution in the surface topography. These figures and their salient features are briefly discussed below:

(1) KAENA POINT (Fig. 4). Three wind maxima are depicted along the ridge of Kaena Point with values of 10, 12 and 15 m/s. The University of Hawaii measurement tower is located on the ridge of Kaena Point and is situated in a "saddle area" between the 12 and 15 m/s maxima indicated in the calculation. An independent measurement of the mean speed by Prof. Ramage (not used as model input) at the 90 foot elevation is 17 mph, which is in excellent agreement with the MATHEW calculated value of 10 m/s at the 150m level adjusted to a common reference level.

(2) KAHUKU POINT (Fig. 5). Two wind maxima are indicated on the ridge of Kahuku Point with values of about 13 and 15 m/s. Regions above 10 m/s in strength have areas of ten to fifteen square kilometers. These maxima appear to be reasonably stable in position in the increased resolution calculations. This is probably due to the greater simplicity of the terrain in the Kahuku region in comparison to the terrain of Kaena Point.

(3) MAKAPUU POINT (Fig. 6). This higher resolution calculation shows a maximum in wind speed nearer Makapuu point in comparison to the results for the whole island of Oahu. The other maxima in the ridge passes and the regions west of Kaneohe Bay appear reasonably stable in location and extent.

(4) DIAMOND AND KOHO HEAD (Fig 7). Solutions for the high resolution case for this part of the island show a large area of speeds greater than 12 m/s between Diamond and Koho Head. Isolated smaller maxima to the north of Diamond Head also are shown.

A summary of the locations of wind maxima for the most frequent July wind data set is shown in Figure 8. The wind energy-rich subregions of Oahu are of two general types; (a) maxima associated with the trade winds flowing both over and around the prominent ends of the islands (Kahuku, Kaena, Mauna Kapu, Makapuu, Koho Head), and (b) the channeling of the flow through the passes of the Koolau and Wainane ranges. In general, the flows over these portions of Oahu appear to have reasonable stability of location in the solutions of increasing resolution. However, further tests at higher resolution are still warranted at this time and will be performed.

3. CRITERIA FOR SELECTION OF PRIME WIND ENERGY SUBREGIONS

The following criteria have been developed for screening the many wind energy-rich regions of Oahu for further study:

- (1) Simplicity or "relative cleanness" of terrain, particularly in the upwind prevailing trade wind direction;
- (2) Representivity of wind data (existing or to be acquired) reflecting the time averaged flow;
- (3) Satisfaction of the assumptions of the diagnostic model;
- (4) Amenability of the site to iterative measurement and calculation for purposes of verifying energy magnitude and spatial extent.

Based on these criteria, it is the consensus of the LLL team that the following sites appear superior and warrant further study of their wind energy potential; Kaena Point, Kahuku Point, and the southern slopes

of Mauna Kapu. It is these areas in which we plan to deploy LSA measurement systems in July and August to verify the nature, location, and extent of the maxima indicated in the preliminary planning calculations.

The July-August data set from these specific sites should also be examined for directional persistence comparable to the trade wind persistence (~70%) in other portions of Oahu with a view to ascertaining if simpler WTG designs could be considered in these environments.

4. CONCLUDING REMARKS

In a very real sense, our preliminary MATHEW calculations are serving as a wind energy prospectors guide and have provided a basis for focusing economical efforts on further wind energy measurement and documentation. The extent to which these tools are of value and cost effective for large wind energy planning will be tested and determined in the next stage of the project.

SITE: HIS

DATE: 07/00/00

TIME: 00/00/00 GMT

RUN: 1

ADJUSTED TO 50. METERS
ABOVE TOPOGRAPHY USING
POWER LAW EXPONENT OF 0.15

DISTANCE EAST - METERS
WIND MEASUREMENTS

GRID ORIGIN
X: 574000. UTM
Y: 2350000. UTM
Z: 0. MASL

FIGURE 1

TOHAW TOPOGRAPHY SITE

MAX IS 900.METERS
ABOVE REFERENCE ELEVATION

DISTANCE EAST - METERS
SITE TOPOGRAPHY

GRID ORIGIN
X: 574000. UTM
Y: 2350000. UTM
Z: 0. MASL

FIGURE 2

SITE: HIS

DATE: 07/00/00

TIME: 00/00/00 GMT

RUN: 1

FIGURE 3

SITE: HIS

DATE: 07/00/00

TIME: 00/00/00 GMT

RUN: 3

PLANE IS 150. METERS
ABOVE TOPOGRAPHY ELEVATION

DISTANCE EAST - METERS
ADJUSTED HORIZONTAL WINDS

GRID ORIGIN
X: 600000. UTM
Y: 2378000. UTM
Z: 0. MASL

FIGURE 5

FIGURE 7

WIND MAXIMA LOCATION SUMMARY

FIGURE 8

REFERENCE:

1. Sherman, Christine A., "A Mass Consistent Model for Wind Fields Over Complex Terrain," Lawrence Livermore Laboratory Report UCRL-76171, October, 1975.

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