echnical Memorandum OTES 3

WEATHER CONSTRAINTS ON AIRBORNE LASER HYDROGRAPHY OPERATIONS

Rockville, Md.
January 1982

U.S. DEPARTMENT OF COMMERCE / National Oceanic and Atmospheric Administration / Ocean Technology and Engineering Services

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UNITED STATES
DEPARTMENT OF COMMERCE
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National Oceanic and
Atmospheric Administration
John V. Byrne, Administrator

Ocean Technology and
Engineering Services
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WEATHER CONSTRAINTS ON AIRBORNE LASER HYDROGRAPHY OPERATIONS

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ABSTRACT. The occurrences of acceptable weather conditions for airborne laser hydrography are documented for seven sites along the U.S. East Coast.

1.0 INTRODUCTION

Airborne laser hydrography is potentially a very fast and cost-effective technique for performing hydrographic surveys. The utility of such a system, however, would be greatly reduced if it were intolerant of environmental parameters and only operated under ideal conditions. This study examines the operational limitations imposed on laser hydrography by weather conditions. An estimate is developed of the probability of favorable weather conditions for airborne laser hydrography operations at seven sites on the east coast of the United States. For comparison purposes, similar estimates are made for launch-based sonar hydrography and for stereo photobathymetry.

2.0 DEFINITION OF FAVORABLE WEATHER CONDITIONS

Suitable weather conditions for airborne laser hydrography are days when the winds are less than 20 knots and when there is no precipitation or fog. Twenty knots was chosen as the upper limit on wind speeds for several reasons. Below 20 knots it is improbable that whitecaps will occur to confuse the sea surface reflection of the laser pulse. Above 20 knots, no experiments have been performed to demonstrate that accurate laser hydrography can be performed. Also, waves caused by winds above 20 knots can resuspend sediments in shallow water and make it too turbid for effective laser surveying. The frequency of occurrence of winds less than 10 knots will also be determined. The effect of wind on water turbidity is expected to be even less for the lower wind speeds.

Fog was defined as existing when visibility was 0.5 nautical miles or less. Fog will attenuate the laser beam and prevent laser soundings from being gathered. Any type of precipitation is expected to have a similar scattering/attenuating effect and will probably preclude laser hydrography operations.

Favorable weather conditions for stereo photobathymetry are more restrictive than for laser hydrography. Stereo photobathymetry requires winds less than 5-7 knots and a "clear day". A "clear day" is one with a minimum 30° solar angle and one-tenth or less of the sky having clouds in it. Fog and precipitation also preclude stereo photobathymetry.

Launch-based sonar is the most weather-tolerant hydrographic system of the three studied. It can operate in various semi-adverse weather conditions including precipitation. It is not operated in winds higher than 20 knots because the sea state (approximately four-five foot seas) would be hazardous to small craft, and because the heave, roll, and pitch of the launch can introduce errors in depth measurement. For safety reasons, launch operations are not conducted in fog.

3.0 COMPUTING THE PROBABILITY OF OCCURRENCE OF FAVORABLE WEATHER CONDITIONS

Seven study sites were selected along the east coast of the U.S. running from Hyannis Harbor, MA, to Indian River, FL. These sites were chosen because they are considered to be representative of various weather conditions, water depths, turbidities, and bottom types which a laser hydrography system will see. The seven sites are: Hyannis, MA; Jamaica Bay, NY.; Severn River, MD; Annapolis Harbor, MD (Because of the close proximity of these last two sites, they are considered to be one general area. Weather data was the same for both); Oregon Inlet, NC; Cape Fear, NC; Indian River, FL.

Historical weather data for the study sites was collected from Climatic Study of Near Coastal Zone, East Coast, U.S. (issued by U.S. Naval Weather Service Command), Summary of Synoptic Meteorological Observations, North American Coastal Marine Areas, Volumes 2, 3, 4, 5, and 6 (May 1970, also by U.S.N.W.S.C.) and the Aerial Photographer's Clear Day Maps. Clear day maps are issued by the U.S. Department of Commerce, NOAA, EDIS, and indicate the number of clear days (one-tenth or less cloud cover) that can be expected from sunrise to sunset that meet the minimum 30° solar altitude requirement of aerial photography for any location in the U.S. The frequency of occurrence of any particular weather condition, e.g., rain, was tabulated and combined with other conditions as described below. Between 100 and 3600 observations were recorded for each table entry.

The various weather conditions were assumed to be independent variables i.e., it does not have to be raining to be windy, although the two variables could occur simultaneously. The cases when they do occur at the same time are accounted for in the probability formulas. Table 1 of probabilities of simultaneous occurrence of wind and rain is included to illustrate that this is not a contributing factor to the final answer, owing to the small size of those probabilities.

The probability of favorable weather conditions for laser hydrography is defined as:

$$P\,(\text{laser}) = 1.0 - P(r) - P(f) - P(w) + P(r)\,P(f) + P(r)\,P(w) + P(w)\,P(f) - P(r)\,P(w)\,P(f)$$

where

$P(r)$ = probability of precipitation

$P(w)$ = probability of wind greater than 20 knots (or 10 knots)

$P(f)$ = probability of fog

The probability of favorable weather conditions for stereo photobathymetry is defined as:

$$P\,(\text{photo}) = 1.0 - P(w) - P(cd) + P(w)\,P(cd)$$

where

$P(w)$ = probability of wind greater than 10 knots (5-7 knot data was not available)

$P(cd)$ = probability of "not clear days" per month

The probability of favorable weather conditions for launch-based sonar hydrography is defined as:

$$P(sonar) = 1.0 - P(f) - P(w) + P(f)\ P(w)$$

where

$P(f)$ = probability of fog

$P(w)$ = probability of wind speeds greater than 20 knots

The application of these equations to the historical weather data gives the probability of favorable weather conditions for the operation of a particular hydrography system. Tables 2 and 3 show the monthly probability of favorable weather for laser hydrography (Table 2 for winds less than or equal to 20 knots, Table 3 for winds less than or equal to 10 knots). Table 4 shows the monthly probability of favorable weather for stereo photobathymetry. Table 5 shows the monthly probability of favorable weather for launch-based sonar hydrography. Figure 1 shows average monthly probability of favorable weather for each system at each of the locations, and the range of the probabilities over 12 months.

The probability of favorable weather is not the only factor in determining relative productivities of different hydrography systems. Each has its own data acquisition rate and so may be able to use available time more or less effectively. For example, in one "favorable weather day," photobathymetry can be performed only three hours per day due to sun angle constraints while launch hydrography can frequently be performed 24 hours a day. The differences in data acquisition rate and the length of an operational day make a direct comparison among the three systems somewhat misleading. Since the purpose of this study was to decide if there were enough favorable weather days for laser operations, this problem of noncomparability will not be addressed.

4.0 CONCLUSIONS

It can be concluded from the tables and figure that laser hydrography can be performed a large percentage of the time. For winds less than 20 knots, favorable laser surveying weather conditions exist between 60.3 and 92.2 percent of the time. For winds less than 10 knots, favorable weather conditions exist between 22.7 and 64.3 percent of the time. In a cost-effectiveness study of laser hydrography (Enabnit, et al.) it was shown that laser surveying need only be done an average of 6 hours per week to be less costly than launch-based sonar by a factor of 6. This study indicates that at least enough favorable weather days exist to meet the 6 hours per week requirement.

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Enabnit, D.B., Goodman, L.R., Young, G.K., Shaughnessy, W.J., The Cost Effectiveness of Airborne Laser Hydrography, NOAA Technical Memorandum NOS 26, December 1978.

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	MARCH	JUNE	SEPTEMBER	DECEMBER
HYANNIS HARBOR				
Rain and 20 Knot Winds	.03	.005	.009	.04
10 Knot Winds	.07	.02	.04	.09
JAMAICA BAY				
Rain and 20 Knot Winds	.02	.004	.01	.03
10 Knot Winds	.07	.02	.04	.07
SEVERN R. - ANNAPOLIS				
Rain and 20 Knot Winds	.02	.005	.007	.02
10 Knot Winds	.05	.02	.03	.05
OREGON INLET				
Rain and 20 Knot Winds	.02	.005	.007	.02
10 Knot Winds	.05	.03	.03	.05
CAPE FEAR				
Rain and 20 Knot Winds	.02	.005	.007	.01
10 Knot Winds	.04	.03	.03	.04
INDIAN RIVER				
Rain and 20 Knot Winds	.002	.002	.004	.003
10 Knot Winds	.01	.01	.02	.02

Table 1. PROBABILITY OF SIMULTANEOUS RAIN AND 10 KNOT (OR GREATER)/OR RAIN AND 20 KNOT (OR GREATER) WIND FOR SELECTED MONTHS

	HYANNIS HARBOR	JAMAICA BAY	SEVERN R. - ANNAPOLIS HARBOR	OREGON INLET	CAPE FEAR	INDIAN RIVER
JANUARY	.65	.64	.64	.65	.71	.83
FEBRUARY	.62	.65	.69	.63	.67	.84
MARCH	.63	.67	.72	.66	.69	.87
APRIL	.74	.71	.77	.74	.78	.89
MAY	.76	.76	.85	.83	.85	.91
JUNE	.71	.82	.85	.85	.85	.91
JULY	.76	.82	.87	.87	.88	.92
AUGUST	.82	.86	.88	.86	.87	.91
SEPTEMBER	.78	.79	.83	.82	.81	.87
OCTOBER	.72	.75	.77	.75	.76	.84
NOVEMBER	.68	.71	.74	.74	.76	.86
DECEMBER	.60	.67	.67	.71	.74	.85

Table 2. LASER HYDROGRAPHY: PROBABILITY OF FAVORABLE WEATHER (NO PRECIPITATION, WIND < 20 KNOTS, NO FOG)

	HYANNIS HARBOR	JAMAICA BAY	SEVERN R. - ANNAPOLIS HARBOR	OREGON INLET	CAPE FEAR	INDIAN RIVER
JANUARY	.23	.30	.24	.22	.23	.36
FEBRUARY	.24	.30	.28	.19	.21	.36
MARCH	.26	.34	.29	.21	.24	.39
APRIL	.35	.39	.34	.27	.29	.41
MAY	.44	.47	.43	.33	.36	.53
JUNE	.42	.50	.47	.40	.39	.59
JULY	.48	.54	.49	.41	.41	.64
AUGUST	.49	.59	.49	.44	.45	.63
SEPTEMBER	.44	.47	.43	.41	.38	.51
OCTOBER	.36	.42	.36	.30	.30	.41
NOVEMBER	.28	.31	.32	.29	.28	.38
DECEMBER	.23	.29	.29	.26	.27	.37

Table 3. LASER HYDROGRAPHY: PROBABILITY OF FAVORABLE WEATHER (NO PRECIPITATION, WIND < 10 KNOTS, NO FOG)

	HYANNIS HARBOR	JAMAICA BAY	SEVERN R. - ANNAPOLIS HARBOR	OREGON INLET	CAPE FEAR	INDIAN RIVER
JANUARY	.00	.00	.07	.06	.06	.09
FEBRUARY	.07	.08	.07	.05	.05	.09
MARCH	.07	.10	.07	.06	.06	.09
APRIL	.05	.06	.09	.07	.07	.10
MAY	.07	.07	.06	.08	.09	.13
JUNE	.07	.04	.03	.04	.04	.08
JULY	.08	.04	.04	.04	.04	.04
AUGUST	.04	.04	.04	.06	.06	.07
SEPTEMBER	.12	.13	.11	.10	.09	.05
OCTOBER	.09	.16	.13	.11	.11	.07
NOVEMBER	.00	.00	.08	.04	.04	.09
DECEMBER	.00	.00	.00	.00	.00	.09

Table 4. STEREO PHOTOBATHYMETRY: PROBABILITY OF FAVORABLE WEATHER (WIND < 10 KNOTS, CLEAR DAY)

	HYANNIS HARBOR	JAMAICA BAY	SEVERN R. - ANNAPOLIS HARBOR	OREGON INLET	CAPE FEAR	INDIAN RIVER
JANUARY	.74	.72	.68	.70	.75	.86
FEBRUARY	.71	.72	.75	.67	.71	.87
MARCH	.68	.76	.77	.70	.73	.89
APRIL	.82	.80	.82	.77	.80	.91
MAY	.80	.81	.89	.87	.89	.94
JUNE	.73	.86	.89	.90	.90	.94
JULY	.79	.89	.92	.91	.93	.94
AUGUST	.87	.91	.92	.91	.91	.94
SEPTEMBER	.83	.86	.88	.86	.85	.91
OCTOBER	.76	.82	.82	.79	.80	.87
NOVEMBER	.74	.79	.79	.78	.79	.88
DECEMBER	.68	.74	.70	.75	.78	.86

Table 5. LAUNCH-BASED SONAR HYDROGRAPHY: PROBABILITY OF FAVORABLE WEATHER (NO FOG, WIND < 20 KNOTS)

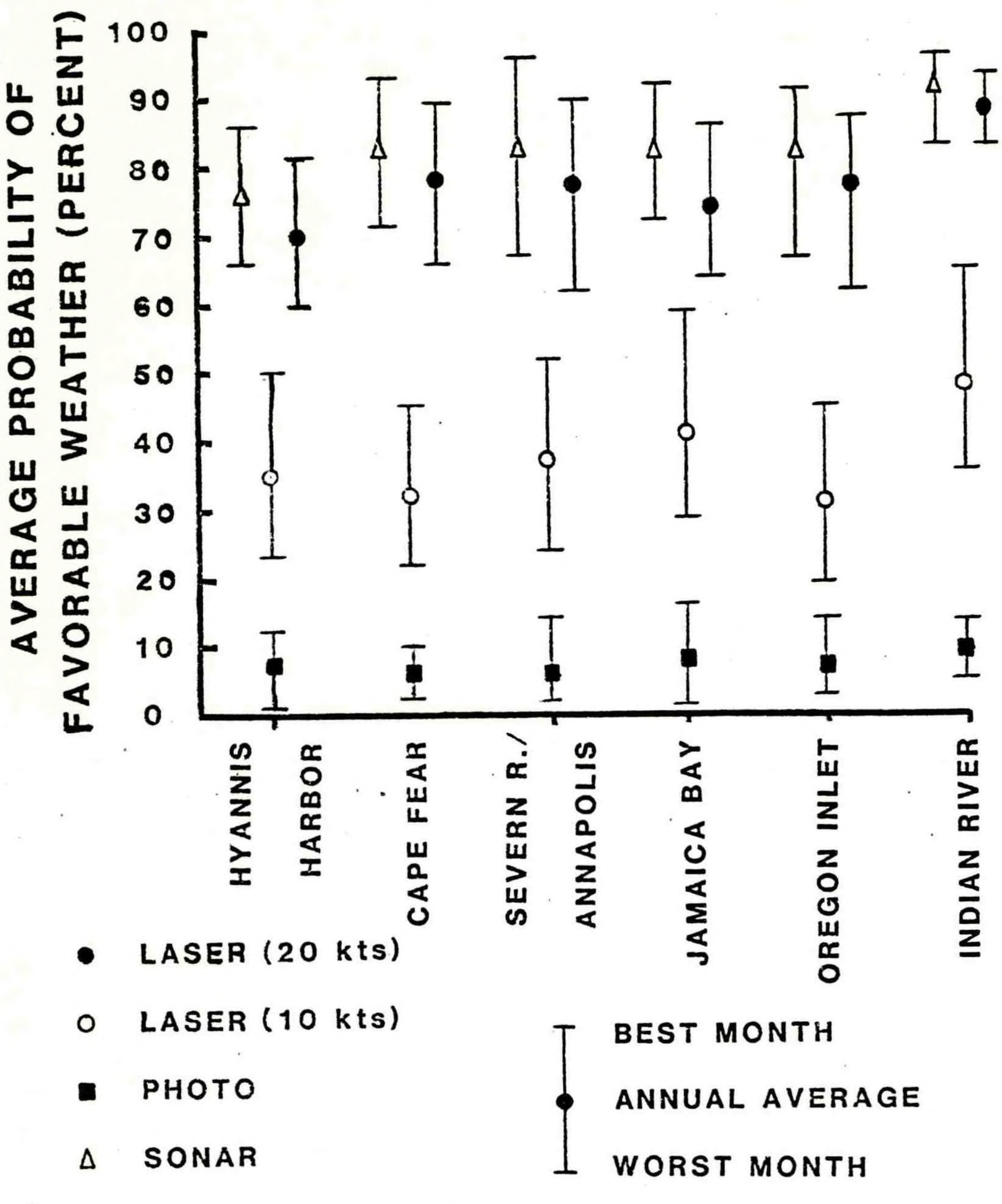

Figure 1. AVERAGE MONTHLY PROBABILITY OF FAVORABLE WEATHER

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