BASELINE UPPER AIR NETWORK (BUAN) FEASIBILITY STUDY

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1.0 INTRODUCTION

Satellites have become an integral part of the Global Observing System of the World Weather Watch. Their observational capabilities have enabled meteorological centers to implement numerical weather prediction models on a global scale. The measurement of radiances, which are transformed into values of temperatures in several layers of the atmosphere, is central to this capability. The process by which atmospheric temperature soundings are derived has evolved substantially over the last several years, and further improvements in the techniques involved are believed possible. At the Extraordinary Session of the WMO Commission for Basic Systems held in 1985, it was agreed that a feasibility study should be undertaken to determine whether improvements would result through the implementation of a baseline upper-air network (BUAN). The BUAN would consist of a small set of stations selected from currently operational observing stations, globally distributed, known to provide high quality soundings on a regular basis. A key element of the network would be the requirement to take soundings coincident with the satellite overpass rather than only at the main synoptic observation times. The United States, as one of the satellite operators and a supplier of soundings on a worldwide basis, agreed to undertake a six- month operational evaluation of the BUAN concept in conjunction with other Members willing to operate observing stations as part of the BUAN.

1.1 Purpose

The purpose of the document is to identify the requirements, procedures, responsibilities and evaluation techniques necessary to determine the feasibility of the baseline network for satellite retrievals. Global networks and operational stations proposed as part of this baseline network are also described.

1.2 Participating Organizations

The National Weather Service (NWS) and the National Environmental Satellite and Data Information Service (NESDIS) have formed a committee to develop the requirements and strategies necessary for conducting the feasibility study. This plan is the result of the committee's effort.

2.0 GENERAL APPROACH AND GOALS

There are two immediate goals and one general goal of the study. The immediate goals are: to determine whether or not the operational satellite soundings can be improved by utilizing the BUAN, and to determine the minimum network necessary to improve operational soundings. The BUAN has been selected in a manner that, should the feasibility study yield positive results, the concept will be operationally implementable with little difficulty. To that end, 50 to 60 radiosonde stations have been identified as the starting point of that determination. It is expected that no more than 20 to 30 stations will be required for a continuing operation; however, it is not possible to determine the correct number a priori.

The general approach consists of having the candidate upper-air stations sample the atmosphere by making observations of standard type as the satellite passes overhead. It is required that observations be globally distributed and include radiosondes, ASAP's, and rocketsondes. These observations will be encoded and transmitted on the Global Telecommunication System (GTS). The calibration and evaluation of retrievals (using either the statistical or physical method in effect) will be performed at WMC Washington. Both NESDIS and NMC will compare the standard retrievals with those obtained from the baseline network to determine the degree of improvement. The actual operation and testing of the baseline network is expected to be completed within six months, but may be extended if further testing seems warranted.

3.0 SATELLITE CALIBRATION TECHNIQUES

The purposes of the BUAN are: to calibrate the satellite retrievals, and to serve as ground truth for the evaluation of the accuracy of the satellite retrievals. The word "calibration" needs clarification. For those involved in satellite sounding work, calibration refers to the process of converting a satellite-measured voltage into the physically meaningful unit of radiance. In this study plan, however, the word "calibration" has a more general meaning. Here calibration is the process of tuning, adjusting, or correcting the satellite retrievals by means of the BUAN to eliminate systematic errors or bias resulting from errors in the calculated atmospheric transmittances and radiance calibrations.

3.1 Statistical Retrievals

New polar-orbiter temperature and moisture sensors, like any precision instruments, require both initial and periodic calibration against known references -- in this case, upper air measurements. The calibrations are currently performed by computing statistics between the worldwide upper air data and the radiances which have been converted to brightness temperatures. These statistics are used to calibrate (i.e., adjust) the satellite measurements to the corresponding upper-air dataset.

After initial calibration, periodic calibrations are performed to ensure continuity of the measurement. The corresponding dataset consists of radiosonde temperature and moisture profiles which are approximately collocated spatially and temporally with the satellite retrievals. About 400 observations comprise this matched dataset over the five latitude belts: 60N-90N, 30N-60N, 30S-30N, 30S-60S, and 60S- 90S. This approach assumes that radiosondes are perfect references and that measurements from different radiosonde manufacturers produce equivalent data.

3.2 Physical Retrievals

Within the U.S., NESDIS is presently experimenting with a new retrieval technique which uses a physical basis rather than a statistical approach. The physical retrieval technique can be described as one in which the retrievals are derived by explicit inversion of the radiative transfer equation. Theoretically, this technique can be accomplished without recourse to the radiosonde network. However, in practice the physical parameters needed are not known well enough to perform the technique accurately. As a consequence, empirical tuning of the satellite retrieval is still required. Since the reliance on physics is crucial to this technique, the radiosonde profiles used in the technique must be of even greater quality. The tuning requires correlations between the mean profiles of temperature and moisture and the associated mean vector of radiances. Regression coefficients may no longer be required in this system.

4.0 REQUIREMENTS

4.1 Baseline Network Requirements

The baseline radiosonde network study requires approximately 50 radiosonde stations globally distributed providing adequate regional and climatological coverage (refer to figures 1a and 1b and to table 1). Additionally, several alternate stations have been identified. A number of coastal stations have also been included in the list even though the representativeness of these soundings may be questioned. The network will also include ASAP (see figures 2 and 3) and rocketsonde stations providing additional observations over remote ocean regions and higher altitudes, respectively. Lidars have not been included because of their experimental nature. Ocean Weather Ships (OWS) have not been included because the increasing cost of their operation has resulted in a steady decline in their numbers. It also seems that there is a high probability that the remaining OWS's will be phased out in the foreseeable future.

4.2 Candidate Networks

4.2.1 Radiosonde

Upper-air observations are produced from a variety of radiosonde systems including those which are manually computed, computer-assisted, and fully automatic. Different radiosonde systems have unique characteristics, and intercomparison tests held under the auspices of CIMO have demonstrated the relative performance of a number of radiosonde systems in current use. Ideally, stations in the baseline network will use systems whose performance characteristics have been tested and documented. The TOVS Study Group has recommended the compilation of a set of adjustments, including factors derived from the CIMO intercomparisons, that might be applied in the satellite retrieval process. It is hoped that these adjustments would be available for use during the evaluation period.

Radiosonde stations were selected based on the criteria set forth below:

a. Geographical coverage: In addition to general spatial coverage, sampling is necessary in both continental and maritime air masses. An attempt was initially made to avoid radiosonde stations in mountainous and coastal regions because their data may introduce ambiguities in the retrievals due to unrepresentativeness of the temperature and moisture profiles within the airmass. Nevertheless, some coastal stations were included because they offered the best quality of data in the region.

b. Reliability of data: Special emphasis was made to select stations based on their record of data receipt and quality as recorded by NMC's and

ECMWF's quality control information. Receipt of stratospheric upper air data up to 10 hPa was also given special importance since satellite radiances are sensitive to the entire vertical extent of the atmospheric temperature structure.

4.2.2 Automated Shipboard Aerological Programme (ASAP)

ASAP is an international endeavor to acquire upper air data from commercial ships of opportunity plying the oceans along major trade routes. Currently there are about half a dozen ASAPs in operation, with three in the North Pacific and an equal number in the Atlantic. The number of ASAPs may expand to a dozen or more by the end of this decade. ASAP offers some advantanges in terms of ship's mobility filling data-sparse ocean regions, the likelihood of greater standardization of measurement, and real- time communications on the GTS. As a result, ASAO baseline observations will provide a more representative picture of the marine environment where satellite retrievals are most useful.

The ASAP Coordinating Committee (ACC) has been formed under the auspices of the WMO to coordinate ASAP activities among participating members. ASAP members have shown an active interest in participating in the baseline upper air network feasibility study. The ACC will be requested to serve as the focal point for coordinating baseline network requirements and activities as they pertain to ASAP.

4.2.3 Rocketsonde

The physical retrieval technique requires some observations to altitudes of at least 50 km. Profiles of atmospheric temperatures to altitudes greater than 50 km can be obtained from the global meteorological rocketsonde network with its accompanying support radiosonde. However, because of their considerable cost, meteorological rockets are currently launched by a few nations throughout the world.

Because of the benefit of this scarce data, participation in the baseline network should be encouraged for the whole network. Rocketsonde stations participating should make special efforts to time their launches whenever possible to be coincident with the satellite overpass. Data collected and processed for this network should be transmitted via the GTS no later than 24 hours after the observation. Only regularly reporting rocketsonde stations have been included.

4.3 Baseline Observation Requirements

The feasibility study will be based on the use of a single polar- orbiter satellite for reasons of simplicity of operation. NOAA-10 will be used for the feasibility study. If the test demonstrates the utility of a baseline network, the procedures should be applied to other polar- orbiting satellites. No more than two baseline observations will be requested from any participant per day. If Members can contribute only one baseline sounding per day, preference is for the daytime observation. Participating Members will have to decide whether to augment their present one- or two-a-day operational program, or retain the same number but adjust the observation time to coincide with the satellite overpass. Members are encouraged to maintain their current synoptic observation if at all possible.

Baseline upper air observations should reach the 10 hPa level at least 60 per cent of the time. ASAP observations should reach 25 hPa at least 60 per cent of the time. Rocketsondes have a minimum height requirement of 50 km.

Participating stations will release balloons (or rocketsondes) so that the devices are at or near the 300 hPa level when the satellite is coincident with the station. Coincidence is defined as the time and position of the satellite as it reaches its highest point in the sky with respect to the earth subpoint. The launch time will be computed by subtracting the average time required to reach the 300 hPa level for that particular time of year and time of day from the time of coincidence.

Established upper-air coding practices will be in effect for all baseline observations.

4.4 Communication Requirements

WMC Washington (NESDIS) will transmit a baseline network notification message to participating Members via the GTS no later than one month prior to the start of the feasibility test. It will be the responsibility of Members to assure distribution of the notification messages to their participating stations. The message will consist of dates and times the satellite will be coincident with the baseline radiosonde and rocketsonde stations. NESDIS will predict these dates and times for at least the first month of the test period. If at all possible, NESDIS will provide dates and times covering periods of three months or more in order to insure for sufficient preparatory time for participating stations. At least one month before the start of the test period, NESDIS will convey to Members operating ASAP's the following satellite orbit information:

a. Polar-orbiting satellite identifier;

b. Date and time of the satellite subpoint for every two minutes of each orbit; and

c. Position information which includes, at a minimum, latitude and longitude for every two minutes of the orbit.

Exact message formats and header information will be distributed at an appropriate time.

5.0 TESTING AND EVALUATION

5.1 Preliminary Planning and Evaluation

Before the field portion of the program is set in motion, NESDIS plans to:

a. Develop and test procedures for transmiting the baseline network notification message via the GTS to the participating Members;

b. Perform a preliminary evaluation on existing archived data of the usefulness and quality of the baseline upper air data to identify whether the candidate stations selected are adequate; and

c. Develop procedures for transmitting satellite orbit information to ASAP.

5.1.1 Upper-air and Rocketsonde Network

The notification message will be transmitted one month before the startup of the actual test. If baseline stations wish, they may actually perform baseline observations for this trial period to identify any potential weaknesses in the procedures.

Participating Members will respond through the GTS with the following verification message:

THE BASELINE NETWORK NOTIFICATION MESSAGE WAS RECEIVED AT XXXXX ON YYYYYY AT ZZZZ.

Here, XXXXX is the station identifier, e.g., 70877; YYYYYY is the date of message receipt (day,month,year); and ZZZZ is the UTC time of receipt. This return message must be transmitted within three days of the initial notification. If no startup notification message was received within 24 hours of the transmission time, the baseline station will transmit the following non-verification message:

THE BASELINE NETWORK NOTIFICATION MESSAGE HAS NOT BEEN RECEIVED AT XXXXX, PLEASE RETRANSMIT.

NESDIS will be responsible for keeping records of the messages transmitted and verified by the participating stations. Baseline upper- air stations not receiving the notification messages or not responding with their verification messages will be contacted as soon as possible to make every attempt to improve their data receipt.

5.1.2 ASAP Observations

NESDIS will produce and furnish the satellite orbit information as described in paragraph 4.4 to the ASAP operators. Participating ASAP operators may wish to perform the following exercise to become familiar with the satellite overpass technique:

a. When the satellite orbit information has been received, the ASAP operator will determine the dates and times the baseline (i.e., coincident) observations could be taken for the next voyage based on the ship's operating schedule.
b. If international satellite communications are being employed for data transmission, the ASAP operator will determine which assigned coded message transmission time slots will be used to transmit the baseline observations.
c. If ASAP operators choose, they may wish to actually perform baseline observations during the trial period to identify any potential weaknesses before the actual evaluation period.

5.1.3 NESDIS Preliminary Planning

A preliminary evaluation will be performed by NESDIS to determine the optimum sample size of the baseline network and adequacy with respect to either the statistical or physical retrieval techniques described above. This activity will utilize the present technique for ingesting and processing the radiosonde data, i.e., satellite/radiosonde correlations performed at synoptic times. Therefore, the technique for determining the impact expected from reducing interpolation-induced errors cannot be evaluated during this phase.

5.2 Operations and Evaluation

5.2.1 Baseline Network Operations

Actual operations will be analogous to the preliminary test including any modifications to the procedures resulting from this early test. All four parts of the TEMP code should be normally transmitted within 4 hours of the baseline observation. The time entered for each part will be to the nearest hour associated with the observation time. Baseline observations coming into NESDIS will be entered into the database daily and correlated with the satellite overpass date and times. NMC and NESDIS will both be responsible for keeping data availability and data quality statistics for each component (upper air, ASAP, and rocketsondes) of the baseline network. A summary report identifying the data characteristics of each network station will be produced every three months and distributed to the participating Members.

5.2.2 Evaluations

NESDIS, as the U.S. weather satellite operator, has been designated the lead agency to plan and evaluate testing of the baseline upper air network. NESDIS will determine the effect of the baseline network on satellite retrievals using whichever satellite retrieval technique is in place, i.e., statistical or physical. NESDIS plans to compare retrievals made from the baseline network versus the present use of synoptic observations. This comparative process usually occurs every two weeks over the span of the feasibility study. Comparative error statistics providing information on the degree of improvement, if any, to be derived from the baseline network will be performed during and at the completion of the test. NESDIS will also report on the adequacy of the baseline network configuration including the minimum number of baseline stations required for an operational network.

NMC routinely obtains the satellite temperature and moisture retrievals from the NESDIS database for use in its analysis and forecast products. NMC will compare the operational retrievals produced from this technique with those produced from the baseline dataset. The temperatures may be produced by either the statistical or physical retrieval technique in effect during the study

5.2.3 Reports

WMC Washington will submit a report to CBS based on the NESDIS and NMC evaluations. The operational and evaluation schedule is shown in figure 4. Centers other than WMC Washington are encouraged to undertake evaluations of the usefulness of the baseline soundings in their operations. Such centers may wish to contact WMC Washington to discuss procedures and results of their studies.

TABLE 1

BASELINE UPPER AIR NETWORK
CANDIDATE STATIONS.

PLOT	STATION IDENTIFIER	STATION NAME	REMARKS
1	01001	JAN MAYEN	
2	01241	ORLAND	NEAR COAST
3	02963	JOKIOINEN	
4	03005	LERWICK	ALTERNATE TO 06011
5	06011	THORSHAVN	ALTERNATE TO 03005
6	07145	TRAPPES	
7	08495	GIBRALTAR	NEAR COAST
8	08509	LAJES, ACORES	NEAR COAST
9	08594	SAL	NEAR COAST
10	10384	BERLIN–TEMPLEHOF	
11	12374	LEGIONOWO	
12	21432	OSTROV KOTEL'NYJ	
13	24959	JAKUTSK	
14	28698	OMSK	
15	34560	VOLGOGRAD	
16	38457	TASKENT	ALTERNATE TO 38687
17	38687	CARDZOU	ALTERNATE TO 38457
18	41024	JEDDAH	NEAR COAST
19	47936	NAHA/KAGAMIZU	
20	48455	BANGKOK	
21	48698	SINGAPORE	
22	54511	BEIJING	
23	58457	HANGZHOU	
24	60020	SANTA CRUZ DE TENERIFE	
25	61052	NAIMEY–AERO	
26	62017	TRIPOLI INT'L AIRPORT	NEAR COAST
27	64650	BANGUI	
28	65578	ABIDJAN	NEAR COAST
29	70308	ST.PAUL	
30	70417	SHEMYA AFB	
31	71600	SABLE ISLAND	
32	71913	CHURCHILL	NEAR COAST
33	71924	RESOLUTE	ALTERNATE TO 71925
34	71925	CAMBRIDGE BAY	ALTERNATE TO 71924
35	71957	INUVIK	
36	72340	LITTLE ROCK	
37	72747	INTERNATIONAL FALLS	

TABLE 1(Cont.)

BASELINE UPPER AIR NETWORK
CANDIDATE STATIONS.

PLOT	STATION IDENTIFIER	STATION NAME	REMARKS
38	76151	ISLA GUADALUPE	
39	76723	ISLA SOCORRO	
40	78954	GRANTLEY ADAMS	
41	80413	MARACAY	
42	91217	GUAM	
43	91245	WAKE ISLAND AIRFIELD	
44	91285	HILO	
45	91366	KWAJALEIN	
46	91610	TARAWA	
47	98327	CLARK A.B.	NEAR COAST
48	61901	ST. HELENA IS	
49	61902	WIDE AWAKE FIELD	
50	61967	DIEGO GARCIA	
51	61996	MARTIN – DE – VIVIES	
52	61998	PROT – AUX – FRANCAIS	
53	63985	SEYCHELLES INT'L AIRPORT	
54	67774	HARARE	
55	68406	ALEXANDER BAY	NEAR COAST
56	68994	GOUGH ISLAND	
57	68994	MARION ISLAND	
58	48219	BELEM	
59	84628	LIMA – CALLAO	NEAR COAST
60	85469	ISLA DE PASCUA	
61	87155	RESISTENCIA AERO	
62	87860	COMODORO RIVADAVIA	NEAR COAST
63	89022	HALLEY	NEAR COAST
64	89050	BELLINGSHAUSEN	
65	89532	SYOWA	NEAR COAST
66	89571	DAVIS	NEAR COAST
67	89611	CASEY	NEAR COAST
68	91765	PAGO – PAGO, SAMOA	
69	91938	TAHITI – FAAA	
70	93944	CAMPBELL ISLAND	
71	94203	BROOME AIRPORT	NEAR COAST
72	94326	ALICE SPRINGS AIRPORT	
73	94610	PERTH AIRPORT	NEAR COAST
74	47778	SHIOMOMISATI	NEAR COAST

TABLE 1(Cont.)

BASELINE UPPER AIR NETWORK
CANDIDATE STATIONS.

PLOT	STATION IDENTIFIER	STATION NAME	REMARKS
75	08001	LA CORUNA	
76	72493	OAKLAND	
77	72208	CHARLESTON	
78	72203	WEST PALM BEACH	
79	72261	DEL RIO	
80	76644	MERIDA	
81	68588	DURBAN	
82	68842	PORT ELIZABETH	
83	94672	ADELAIDE	
84	98327	NEQUEN	NEAR COAST

BASELINE UPPER AIR NETWORK
ROCKETSONDE CANDIDATE STATIONS

85	20046	OSTROV HEJSA
86	04202	THULE A.B.
87	71124	PRIMROSE LAKE
88	34560	VOLGOGRAD
89	47513	RYORI
90	72402	WALLOPS ISLAND
91	72269	WHITE SAND
92	72391	POINT MUGU
93	91162	BARKING SANDS
94	74794	CAPE KENNEDY
95	78861	COOLIDGE FIELD
96	91366	KWAJALEIN
97	43373	THUMBA
98	61902	WIDE AWAKE FIELD
99	89542	MOLODEZNAJA

FIGURE 1A

BASELINE NETWORK UPPER AIR PROGRAM
CANDIDATE STATIONS

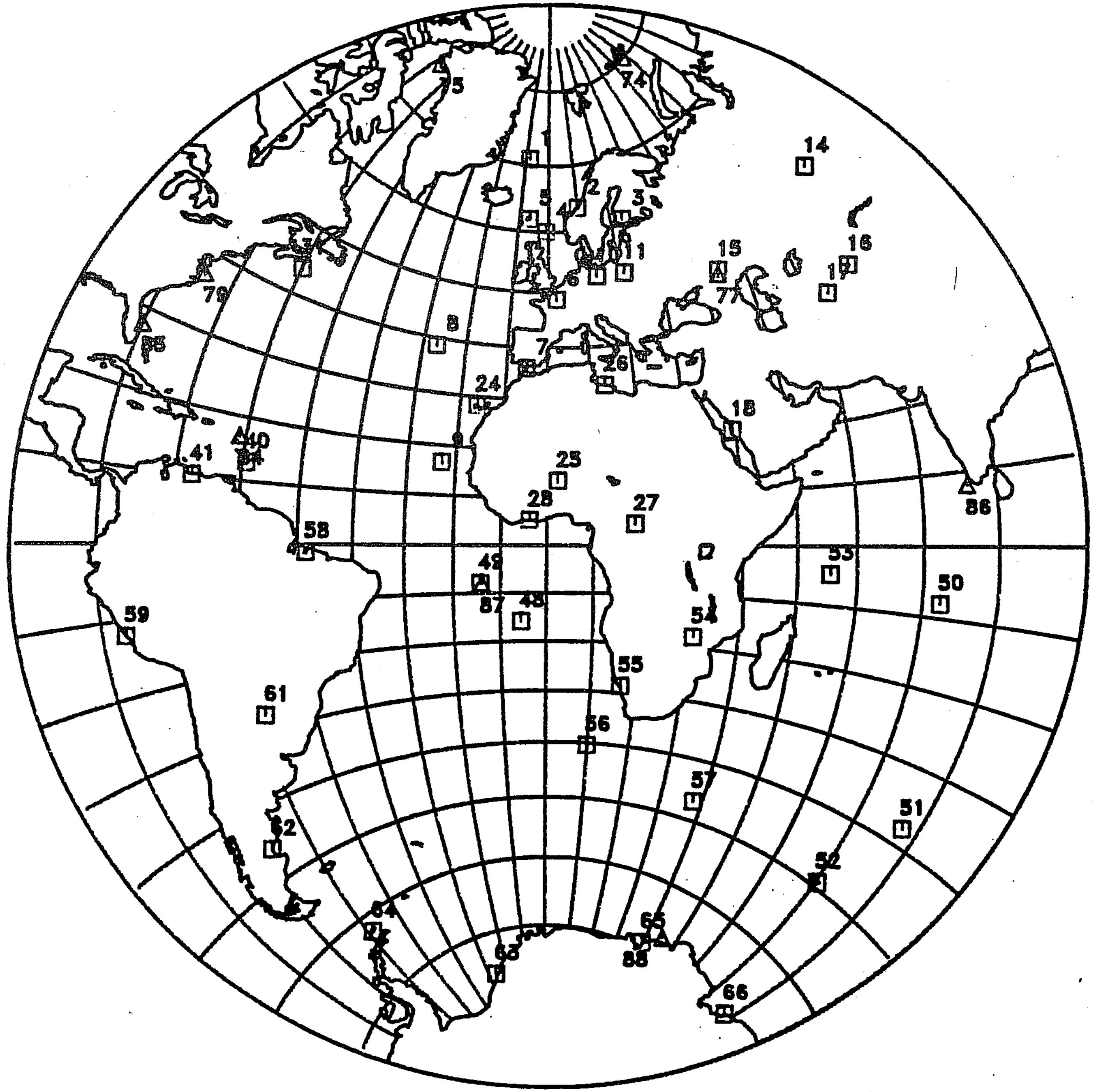
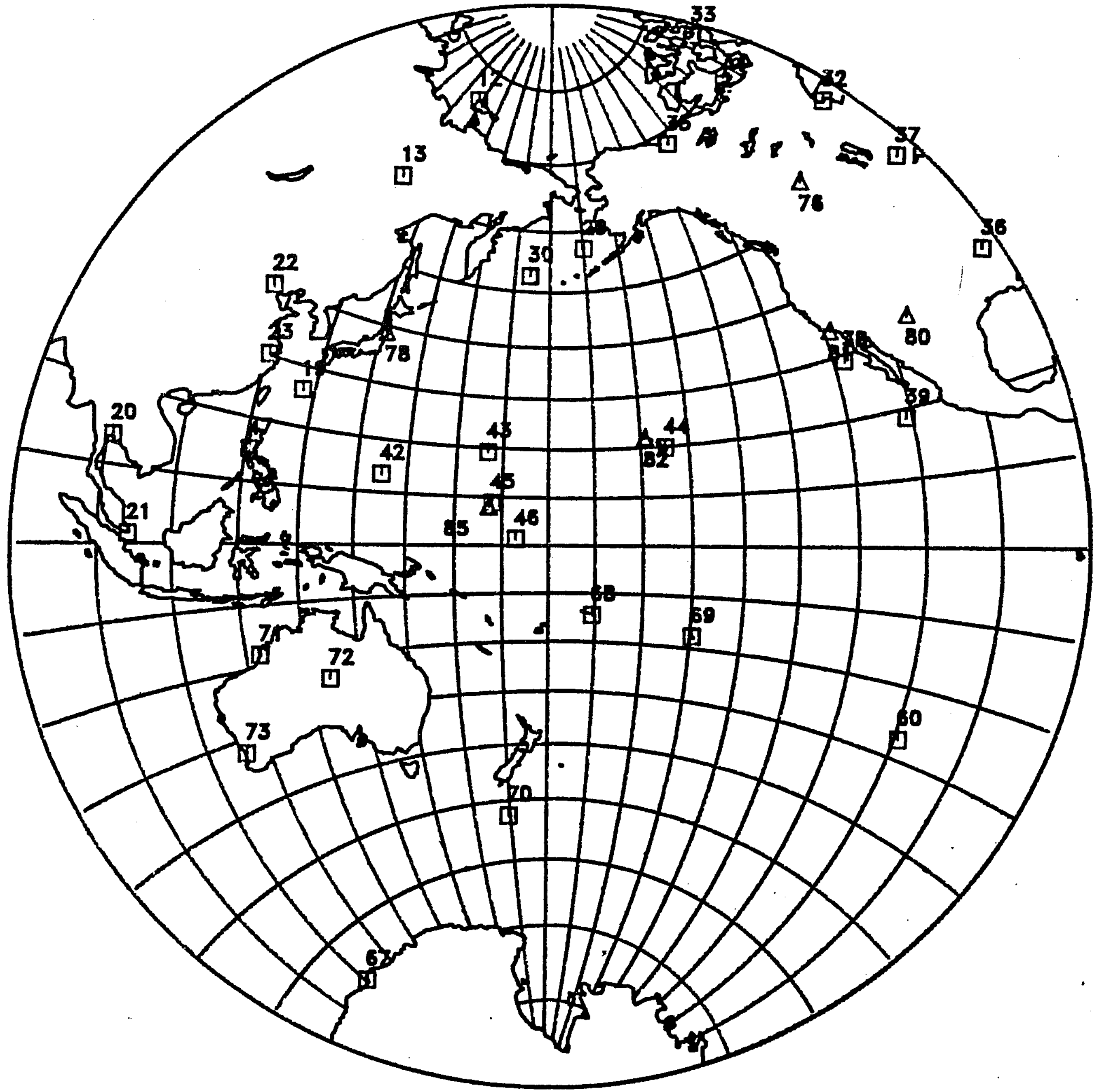


FIGURE 1B

BASELINE NETWORK UPPER AIR PROGRAM
CANDIDATE STATIONS



AUTOMATED SHIPBOARD AEROLOGICAL PROGRAMME
(ASAP) Routes
CANADA—— US-·-·- FUTURE ·······

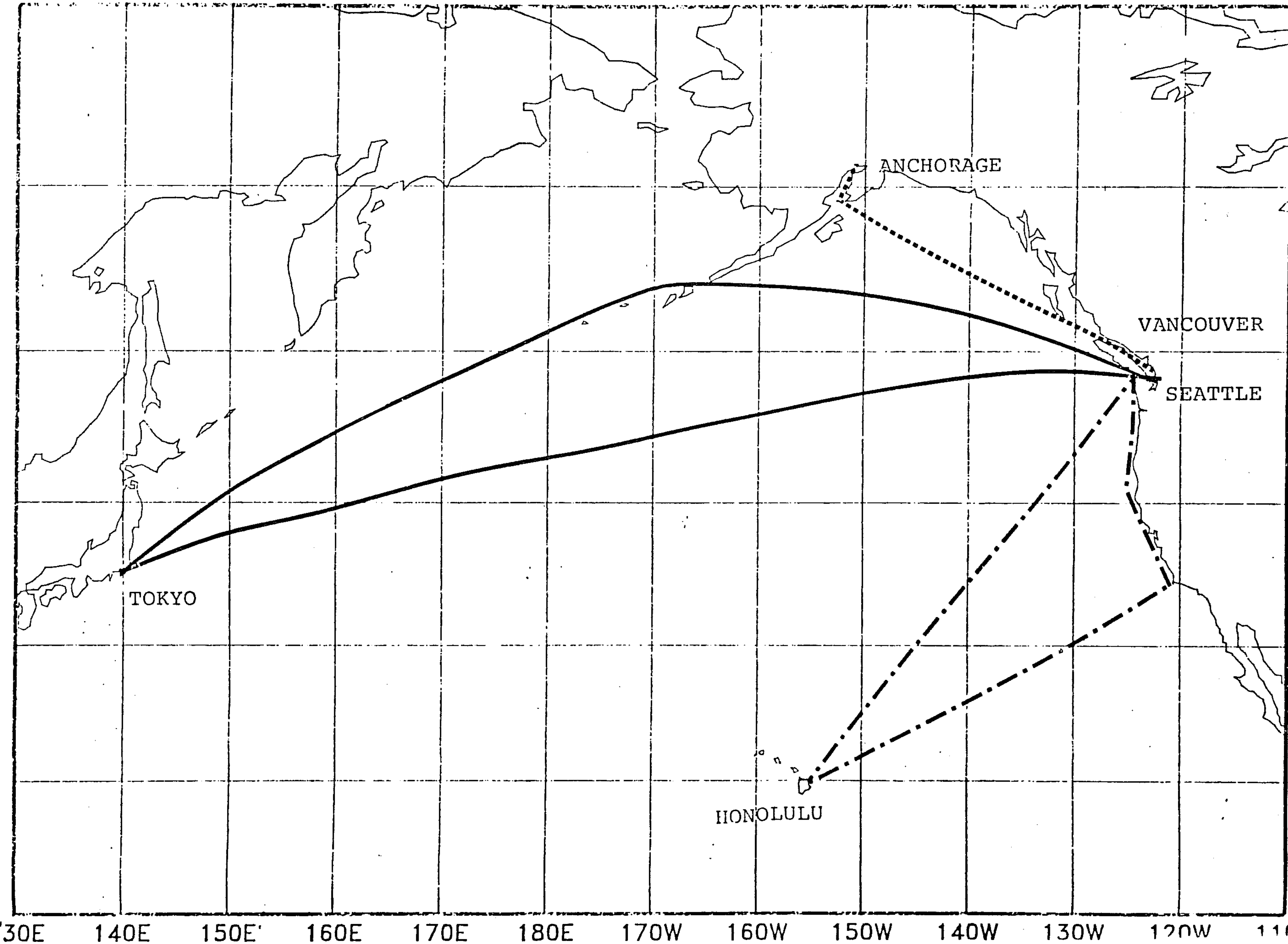
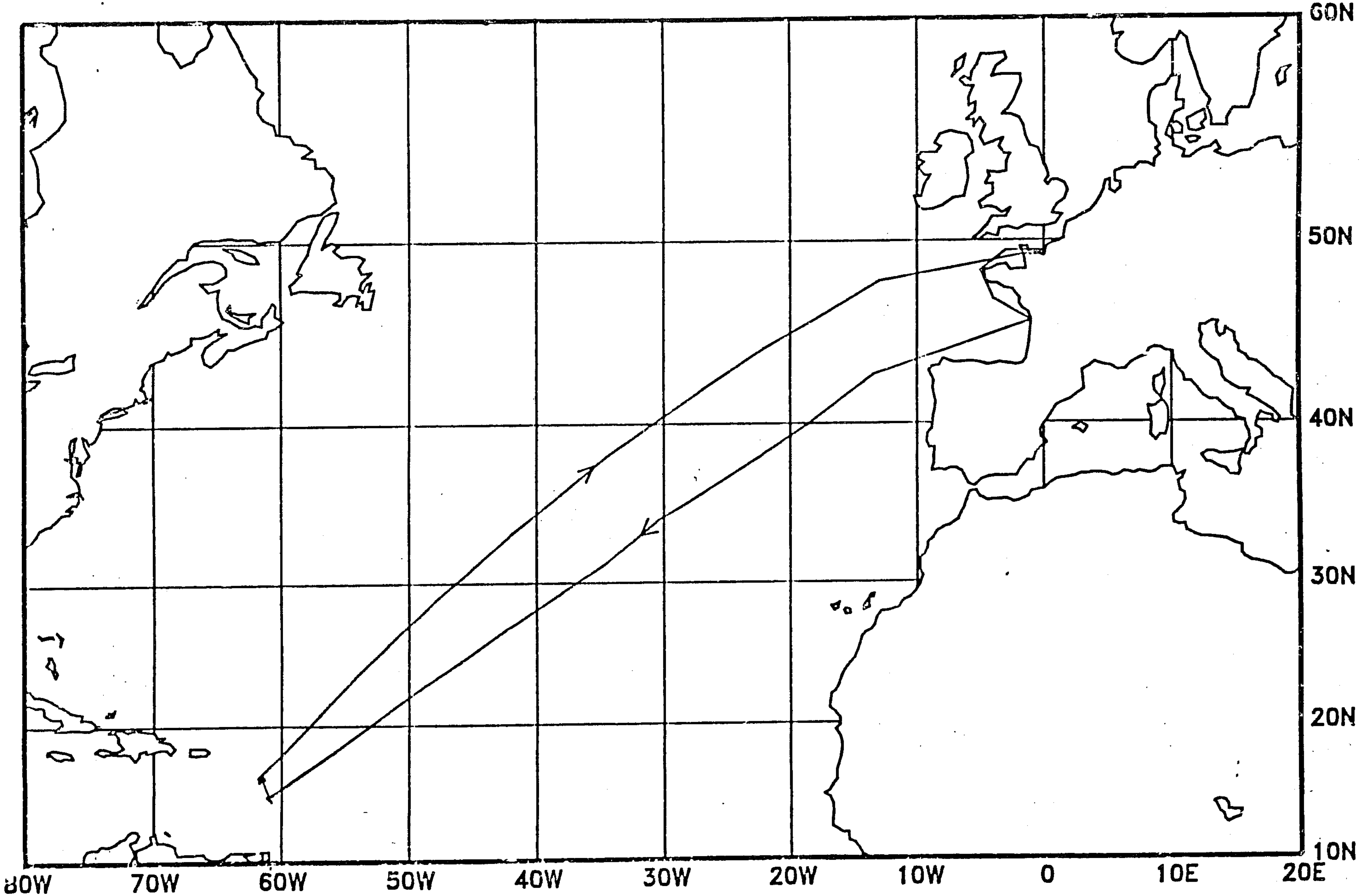


FIGURE 3.
FRENCH ASAP ROUTES



BUAN EVALUATION PLAN