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An Operational Évaluation of the FE-CASP Numerical Model Output and Related Displays during CASP

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ABSTRACT

In support of the Canadian Atlantic Storm Program (CASP), a dedicated Forecast Centre was operated in Bedford, Nova Scotia, January 15 to March 15, 1986. The Centre was staffed by operational meteorologists from several AES Forecast Offices. An important goal of the Forecast Centre was to assess a wide variety of enhanced observational data, newly developed forecast guidance products and experimental graphics display equipment.

This report deals with an operational evaluation of the special Finite Element Model (FE-CASP), developed by RPN and run at CMC as it was displayed and used at the 'CASP' Forecast Centre. An objective assessment of the 'FE-CASP' model is made in comparison with other Canadian and U.S. models available in Bedford. A second more subjective assessment is made of the various data display formats, their accuracy, and their usefulness to forecasters.

A number of displays were considered very useful, especially those involving precipitation. The display of time-series of rain rates and surface winds at specific sites generated much forecaster interest. It is recommended that this type of guidance be sent in 'hard-copy' format to Atlantic Region Weather Centres twice daily as soon after data time as possible for operational use and further testing.

CONTENTS

1. INTRODUCTION

As part of the Canadian Atlantic Storms Program (CASP) the Numerical Modelling Research Division (RPN) developed a high-resolution version of their already operational finite element (FE) numerical weather depiction model. This CASP version (FE-CASP) of the model is similar to the operational (continental) version except for the following:

- Maximum horizontal resolution is 100 km vs. 190 km for the continental FE.
- It uses a different topographical representation which includes a more precise land/sea boundary.
- It uses a higher resolution sea surface temperature analysis.
- It contains enhanced physical parameterization.

Significantly more detail on the model is provided by Benoit (1985).

Not only did CASP provide an excellent opportunity for model experimentation, it also allowed RPN the chance to provide direct support by delivering the FE-CASP forecasts to the special CASP Forecast Centre (Danks, 1986) in Bedford, N. S. In addition to providing the Forecast Centre with traditional facsimile charts, a wide variety of experimental displays were made available via the Remote Image Display Systems (RIDS) (Findleton, 1985) operating on an IBM PC-XT computer. This included such displays as vertical cross sections, temperature profiles and time series of various parameters.

This report provides an evaluation of the FE-CASP from the perspective of the operational meteorologist. Both the model's isobaric and precipitation forecasts are assessed and compared with other available NWP products. In addition, an assessment of the various experimental displays available through RIDS is given. Recommendations regarding which of these displays might be operationally useful are presented.

2. COMPARISON OF THE BEHAVIOUR OF THE 'FE-CASP' MODEL WITH OTHER AVAILABLE MODELS

2.1 APPROACH

FE-CASP forecasts have been compared with forecasts from three currently available models: CMC's spectral model, CMC's continental version of the finite element model (FEM) and the U.S. National Weather Centre's nested-grid model (NGM). There were two areas of particular interest in evaluating performance of these four numerical models.

First, the surface isobaric prognoses were of interest with respect to:

a) depth of pressure centre as an indicator of a model's handling of the dynamics of the situation and its ability to predict marine wind fields;

b) track and speed of storm centre as an aid to accurate weather prognosis (e.g. timing and type of precipitation).

Second, the quantative precipitation forecasts (QPF) were of interest as precipitation is the most important inland public forecast parameter in winter.

2.2 ISOBARIC PROGS

2.2.1 Pressure.

36 hour forecasts from each of the four available numerical surface prognostics were verified with respect to a) central pressure, b) vector error of position, and c) speed, for the main low pressure centre in each of the 16 CASP intensive observation periods (IOP's). As might be expected all four models were too weak or shallow at 36 hours with the central pressure of the 16 storms studied in CASP. The CMC Finite Element (FEM) was a little too deep on two occasions (2 mb and 6 mb) and the CMC Spectral once (4 mb). In the remaining cases for which progs were available, the lows were not deep enough on 36 hour progs. Biases were as follows:

CMC Spectral	+ 8.2 mb	16 Storms
CMC F.E.M.	+ 8.3 mb	14 Storms
CMC FE-CASP	+ 10.6 mb	16 Storms
U.S. Nested Grid	+ 12.3 mb	12 Storms

2.2.2 36 Hour Prog Position

The error in position (Fig. 1) is the vector error taken to the nearest 60 nautical miles (whole degree latitude) and 8 points of the compass. The reference direction is the actual track of the low centre. The origin (centre of concentric circles) is treated as the actual position of the storm centre at the verifying time. The error vectors are added for each 8 directions to form an "ERROR ROSE". The dots define the incremented vector lengths for all previous storm cases. Perfect prognostics (zero error) cannot be shown but are used in calculating mean (absolute) error.

The circles in Fig. 1 are drawn at 60 n.m. (1° latitude) increments.

For example (Fig. 1) the 'FE-CASP' model was left of track and fast with a vector error of 3° latitude on one (only) occasion during the 16 IOP's. This model forecast the correct track for 36 hours, but was slow on three occasions by 4, 2, and 4 degrees latitude.

Mean absolute errors lay between 2.0 and 2.6 degrees latitude for the 4 models. In this assessment, the FE-CASP and U.S. NGM (which did not deepen lows as much as the two primary CMC models) had marginally better performance:

CMC Spectral	2.25°	Lat.	mean	absolute	error
CMC F.E.M.	2.6°	Lat.	"	"	"
CMC 'FE-CASP'	2.1°	Lat.	"	"	"
U.S. Nested Grid	2.0°	Lat.	"	"	"

2.2.3 Speed (Fig. 1).

Speeds of low centres were calculated with reference to the actual track of the surface low centre.

Thus, in Fig. 1, lows which were forecast too fast lie above the horizontal line through the diagram's centre and those which were slow lie below it.

There was a pronounced tendency on the part of the models to be slow with progged positions. This was most pronounced in the U.S. Nested Grid which was slow in 8 out of 9 cases. Even the CMC regular Finite Element Model, which was slow and fast an equal number of 6 cases, was more than 2 degrees fast in 36 hours on only one occasion.

Model	Fast	Slow
CMC Spectral	5	8
CMC F.E.M.	6	6
CMC FE-CASP	3	8
U.S. NGM	1	8

2.2.4 Track.

As with speeds, forecast tracks were compared to the track of the actual centre of low pressure. In Fig. 1 those lows which were forecast left of track lie left of a vertical line through the diagram's centre. Thus we see that the 'FE-CASP' model forecast 6 major storms too far left of track, but only 2 too far right. The ramaining 8 storms had their track correctly forecast, including 3 with correct speed (which, since they fall at the origin of the diagram, cannot be plotted).

In general all numerical progs were more accurate with respect to track (displacement normal to track) than with speeds. However, it should be recognized that a one degree lateral error in track and thickness would likely mean a major difference in precipitation type (rain vs. snow) or amount while one degree of forward speed means only 1 or 2 hours in timing of precipitation. There was a distinct tendency on the part of the two mainstream CMC progs (FEM and Spectral) to be right of track when too fast and left of track when too slow.

2.3 PRECIPITATION FORECASTS (See Fig. 2).

24 hour actual precipitation amounts ending at 1200Z each day from February 1 to March 15, 1986, were considered. Corresponding 12 to 36 hour model QPF periods from 0000Z data were compared. Observing sites at Halifax (YAW), Sable Island (WSA) and St. John's (YYT - Feb. only) were studied.

The bar graphs in Fig. 2 were devised subjectively to best illustrate the wet or dry biases of the models. The horizontal length of the bar is proportional to the number of occasions each model fit the specified category. The number is plotted within the bar. 'Dry' biases are shown to the left and 'wet' to the right. Amounts of precipitation were not verified, although the second display considers only amounts of 5 mm or more.

This assessment confirmed subjective impressions that the regular FEM model was "wet" and the CMC spectral was quite "dry". The 'FE-CASP' and U.S. nested grid models were intermediate between the two.

On days when 5 mm or more of precipitation fell, all models were too dry but the "wettest" one, the FEM, was clearly preferable. On the other hand, the CMC spectral was not acceptable for precipitation forecasting due to its consistent "dry" bias.

It is important to note that these results were valid in the early months of 1986 only. Precipitation forecasts are very sensitive to model changes and results are not likely fully applicable at present.

3. ASSESSMENT OF UTILITY OF METEOROLOGICAL DISPLAYS AVAILABLE TO 'CASP' FORECASTERS ON THE REMOTE IMAGE DISPLAY SYSTEM (RIDS) FROM CMC MONTREAL.

3.1 THE DISPLAY SYSTEM (RIDS):

This use of the RIDS during CASP is described by Jim Abraham (1986). In general the system was not user friendly. The display and manipulation of over 100 charts in 14 different series in 4 data bases was complex and time consuming. However, considerable use was made of displays on a selective basis and each of the 'CASP' forecasters provided an assessment of the usefulness of products.

3.2 DESCRIPTION OF PRODUCTS AVAILABLE.

Samples of each of the 14 series of meteorological displays available through RIDS are shown in Figure 3A, 3B, and 3C. On the RIDS video display these charts appeared polychromatically (red, white, grey and blue). The samples shown in Fig. 3 were produced by a dot-matrix printer attached to the PC-XT. The photocopying and reduction process have, unfortunately, left the monochromatic copies in this report with limited contrast.

The displays can briefly be listed as follows:

3.2.1 Quebec (CMQ) Data Base: (QUE)

This display (Fig. 3A) is derived from the Finite Element Model and is used operationally by the "Centre Meteorologique du Quebec". It is available twice daily from 'FEM' runs.

#1) FEM QPF in 3-hour intervals from 6 to 30 hours (8 charts) plus 24 hour QPF ending at 33 and at 36 hours from data time.

#2) FEM thickness (1000 - 500 mb) and 500 mb vorticity at 6-hour intervals from 0 to 24 hours plus 36 hours (6 charts total).

3.2.2 'CASP' Data Base 1 (DB1)

There were three 'CASP' data bases set up. All three (DB1, DB2, DB3) were available at about 1000Z from the 'FE-CASP' model which ran once daily. Unfortunately, by the time the new model became available, data in the previous display was 34 hours old and too far degraded to be reliable. The displays in Fig. 3B were all available at 6 hour intervals from 0 to 36 hours from data time and were horizontal maps with geography (7 charts each display).

#3) 850 mb relative humidity (%) and 1000 - 700 mb thickness.

#4) MSL pressure, isotachs (5 kt intervals), and wind arrows (direction and strength).

#5) 6-hour QPF from 0 to 36 hours (1,2,5,10 mm isopleths) and a single thickness line representative of a rain/snow boundary. The fact that the precise nature of this line was never documented in any manuals or on the charts was typical of many 'loose ends' in the chart displays. However, this could be defined and should not affect the future utility of any of these displays.

#6) 6-hour split QPF (rain/snow) from 0 to 36 hours with thickness line as in #5. (Rain in blue and snow in white on the CRT display).

3.2.3 'CASP' Data Base 2 (DB2)

These displays (Fig. 3C) were vertical cross-sections at 6 hour intervals from 0 to 36 hours (7 charts) on two different baselines: one north-south through the Maritimes and shelf waters, and the other from Cape Cod to the Gulf of St. Lawrence.

#7) Isotachs from 1000 to 100 mb level at 10KT intervals. (6 hour intervals on 2 baselines = 14 charts)

#8) Temperature/dew point spread and vertical velocity from 1000 to 100 mb (14 charts as in #7).

3.2.4 'CASP' Data Base 3 (DB3)

These displays (Fig. 3D) are time series 0 to 36 hours at 5 land (YAW,WSA,YFC,YSU,YYT) and 7 sea points in the Atlantic Region. (12 charts in each series: one per point).

#9) Split rain or snow rates (mm/6hr). Note: on the video display rain was shown in red, snow in white.

#10) Relative humidity (%) vs. pressure level (up to 750 mb) at 6 hour intervals to 36 hours (7 profiles/chart).

#11) Temperature vs pressure level (up to 750 mb) at 6 hour intervals to 36 hours.

#12) Production of latent heat: Sigma levels 0.25 to 1.0 vs time.

#13) Turbulent energy: Sigma levels 0.73 to 1.0 vs time.

#14) Surface wind (m/sec) and wind stress (pascals) vs time.

3.3 ASSESSMENT OF PRODUCTS BY FORECASTERS

In general it was not possible to assess the accuracy of display formats objectively due to lack of time. Forecasters' acceptance or rejection of guidance depended more on the parameter depicted and its applicability to forecasts or on the clarity of the format.

The following assessment was compiled from 3 main sources. First, from a written survey made of all CASP forecasters near the end of the field project. Second, from written and tape-recorded comments made by forecasters while on shift during the project. And third, from observations of how the products were being used on shift and from ongoing discussions with the forecasters.

a) Some displays were rejected because the output parameters were not direct forecast variables or were difficult to interpret. For example, Format #12 (latent heat), #13 (turbulent energy), or #4 (wind stress) were judged difficult to incorporate into forecast production.

b) Some displays were rejected as being difficult to read. These included formats #10 and #11 where 7 vertical profiles were placed on one chart. It was suggested that temperature and dew point could be combined to give a low level tephigram prognostic for one time. Another suggestion was that no more than 3 profiles be placed on one chart.

c) The choice of only two "baselines" for the vertical cross-sections in "DB 2" was considered unduly restrictive as the baselines did not usually fit the expected storm track. It was suggested the ideal situation would be an interactive system where any baseline could be selected in formats #7 and #8.

d) There was a consistent preference among forecasters for 3-hour rather than 6-hour QPF where mesoscale precipitation elements could be followed. In practice this resulted in a universal preference for Format #1 (FEM 3-hour QPF from Quebec data base) rather than #5 (FE-CASP 6-hour QPF). Display Format #1 was the most popular of all 14 received (shown in Fig. 3A).

e) Interest in QPF is also manifest in the frequent forecaster use of Format #9, the 0 to 36 hour rain/snow rates. The concept was easy for forecasters to visualize and provided a continuous readout at the 12 selected points. Forecasters were impressed by subjective post-comparisons between actual hourly reports and the rain/snow rates and change-over. Unfortunately the precipitation rate frequently went off scale in major storms exceeding 10 mm/6 hour.

f) There was considerable interest by forecasters from outside the Maritimes (especially those who had worked in Montreal) in Format #2, the FEM thickness and vorticity analysis at 6 hour intervals. Displayed together these fields allow a simultaneous assessment of the two terms in the quasigeostrophic omega equation (Trenbreth, 1978) and on several occasions demonstrated very good correlation with the cloud field.

g) There were hardware problems at times with the RIDS - PC printer and the device was slow. Despite this, there was a strong preference for hard copies for briefings, for archives, and simply to calculate and modify for point forecasts at YAW (Halifax) and WSA (Sable).

h) Perhaps because of the availability of many surface isobaric prog charts and the facility most forecasters have in modifying them synoptically, surface wind forecasts such as Displays #4 or #14 generated little interest amongst forecasters. However, Display #14, a time cross-section of surface wind, was of some interest in site specific forecasts done for WSA (Sable).

3.4 SELECTIVE VERIFICATION OF 'DATA BASE 3' PRODUCTS

Because of forecaster interest in QPF precipitation rate at points and in the new format of time forecasts of precipitation, wind, and temperature soundings at fixed points, some verification was done. They are attached as Figures 4A to K, 5, and 6 respectively.

General comments arising from this verification are noted below. More specific comments related to eleven individual cases appear with the outputs displayed in Figure 4 (time series precipitation rates).

3.4.1 Split (Rain/Snow) Precipitation Rates

a) Refer to Figure 3D - Display #9 and Figure 4. Since directly observed precipitation rates are not normally available at observing sites on a reliable, hourly basis in winter, verification proved difficult. Further discussion of these problems is contained below. It may be in many cases that the forecast is just as accurate as the uncertain observed data. Even though difficult to observe, precipitation rate is of critical interest to the public and an attempt at verification is essential.

b) Trends in precipitation seem quite good, although timing is sometimes in error. Presumably if an upstream station timing is off (eg. Yarmouth), adjustments can be made downstream (eg. Halifax, Sydney).

c) There was a tendency to forecast some rain mixed with snow at the peak of a warm sector when none occurred (eg. YSU Mar 7 Figure 4D, YFC Mar 7 Figure 4E, YAW Jan 30-31 Figure 4A), but in general the change in type (rain vs snow) was well forecast.

d) The FE-CASP precipitation rate progs tended to be slow in forecasting onset of precipitation. (Slow in 50% of cases and fast in only 20%). This fits the trend to slowness of pressure centres noted in Section 2.2.3 and Figure 1.

e) Forecast precipitation rates run 'off-scale' in most storms. Perhaps some sort of inverse logarithmic scale could be used which would be sensitive to lighter rates but could depict current 'off-scale' amounts (> 10 mm/6 hr) also.

f) Precipitation rate charts were not available during 'CASP' (downloaded, labelled, copied) until at least 12 hours after data time. By this time the most accurate part of the forecast had expired and the remainder was downgraded. If the standard 'FEM' output could be used with punctual facsimile output, perhaps this time could be cut to a more acceptable 3 or 4 hours.

g) Recording gauges remain covered when temperatures are near or below freezing. Thus rain, when mixed with snow or ice pellets, is not recorded continuously. (Eg. in Figure 4K and 4L).

h) Snow accumulating on the ground is difficult to measure in strong winds usually accompanying major storms. (Egs. in Figure 4D and 4H).

i) Even in "rain only" situations accumulations are only reported every few hours at best. (Eg. in Figure 4B). Precise verification is subject to availability of tipping-bucket rain gauge traces.

j) The observed precipitation rates as plotted on charts in Figures 4A to 4K are somewhat subjective. The timing of precipitation onset or change from snow to rain should be fairly reliable but rates are not.

   a) Snowfall rates are based on the fairly reliable relationship with visibility but must be subjectively adjusted in high winds.

   b) Rainfall rates are based on intensity (light, moderate, heavy) but with considerable subjectivity in the broad range from light rain (R-) through "R-INTMT", "RW-", to 'R--' or 'L-'. Fog or mist interfered with subjective assessment of rates associated with R- as well.

3.4.2 Surface Wind Time Series.

a) Refer to Figure 3D - Display #14 and Figure 5. The wind forecast for Sable Island for the three cases tested was quite impressive. The trends for Jan. 24-25, Mar. 2-3, and Mar. 7-8, were quite good.

b) Timing was 2 to 4 hours slow for all cases, a trend which was noted previously in Section 2.2.3.

c) The forecast error which develops after 24 hours on Jan. 25 is somewhat of an anomaly. The offending meso-scale surface ridge lies over Sable Island (WSA) at Jan. 25 1200Z. Forecast and actual pressure charts are included in Fig. 5.

3.4.3 Temperature Vertical Profiles

a) Three examples of 24 and 36-hour forecast temperature profiles for Sable Island are shown in Figure 6 along with the verifying soundings. All forecasts appear to be too warm and differences are so large as to suggest that they would not be reliable enough for routine use.

b) In Figure 6a, the 36-h forecast sounding for 1200Z January 25, is 10°C too warm below 930 mb and perhaps suggests too much heat flux from the water as cold air was being advected over the sea.

c) The forecast profiles from 0000Z February 5 (Figure 6b) and 0000Z March 2 (Figure 6c) suggest that much of the error was due to the slowness of the FE-CASP to advect cold air behind a surface low. In Figure 6b, for example, the 24-hour profile verifying at 0000Z February 6 was forecast quite well; however, the marked cooling which took place between 0000Z and 1200Z was missed. Similarly, in Figure 6c, cooling that was forecast to occur between 0000Z and 1200Z on March 3 was actually well underway in low levels by 0000Z.

4. CONCLUSIONS

The 'FE-CASP' numerical model proved to be very competitive with the FEM and other models with respect to the parameters which were verified, ie., central pressures and positions of lows and precipitation accumulations. However, the 'FE-CASP' did not demonstrate any superiority in forecasting these parameters.

Through the special displays of model output, the 'FE-CASP' did demonstrate the ability to forecast, with some accuracy, certain small scale detail, particularly in the precipitation. Since similar special display products generated from other models' outputs were not available, however, it is not possible to say with certainty that such mesoscale detail would not have been possible from the FEM. However, it was evident from the 3-hourly QPF charts generated by the FEM and available in the Quebec Data Base (see section 3.2.1), that a certain amount of small scale detail, not seen on conventional products, is available from the FEM.

Many of the special displays which were available, proved to be extremely valuable to the operational forecasters during CASP. In particular, the time-series displays of precipitation rate (with discrimination between rain and snow) and the 3-hourly QPF charts were found to be useful in preparing inland forecasts, while time-series displays of winds were helpful in preparing site specific marine forecasts.

On the other hand, temperature profile forecasts from the 'FE-CASP' did not demonstrate adequate skill to warrant operational consideration at this time.

5. RECOMMENDATIONS

Based on the above conclusions the following two sets of recommendations are made. The first deals with items which could be implemented immediately, while the second set deals with recommended direction for future research and development.

For immediate consideration it is recommended that:

(1) Experimental Guidance should be supplied to Atlantic Region Weather Centres as follows:

a) Split precipitation rate charts (Figure 3D - Display #9) for selected sites.

b) Surface wind (omit wind stress) (Figure 3D - Display #14) for selected marine locations.

c) 3-hourly QPF (Figure 3A - Display #1) as received at CMQ, Montreal (8 Maps).

(2) The 'FE-CASP' (or equivalent high-resolution version of the FE model) would be the preferred source model, but only if it could be run in a realistic operational time frame. Otherwise, the coarse FEM should be adequate for the purpose; however, tests would have to be conducted to ensure that the coarse model is able to provide realistic detail.

(3) The Guidance should be made available twice daily as quickly as possible after data time (the forecasts' advantage diminishes rapidly as they are delayed).

(4) This guidance should be received automatically, preferably in hard copy.

(5) Formats should be clearly labelled. Initially the following changes are suggested:

a) Precipitation rates should remain on scale for all but extreme events.

b) Wind speeds should be in 'knots' and wind stress is not required.

(6) Monitoring and verification of these charts should take place as 'ODIT' projects at field offices receiving the guidance with continuing feedback to CMC.

For further research and development, the following suggestions are made:

(7) A high resolution model would appear desirable for AES weather centres. However, there is also scope for considerable improvement in synoptic scale numerical forecasting of "explosive" winter storms. Further development should have improvements in both scales as a combined goal.

(8) Priority should be given to providing such an improved model to the weather centres in an operational time frame. Ideally, forecasts out to 24 hours from a high resolution model would be available at a weather centre within 2.5 hours of data time. Longer range guidance (24-28 hours and beyond) from a coarser resolution model could follow as late as 4 hours after data time.

6. REFERENCES

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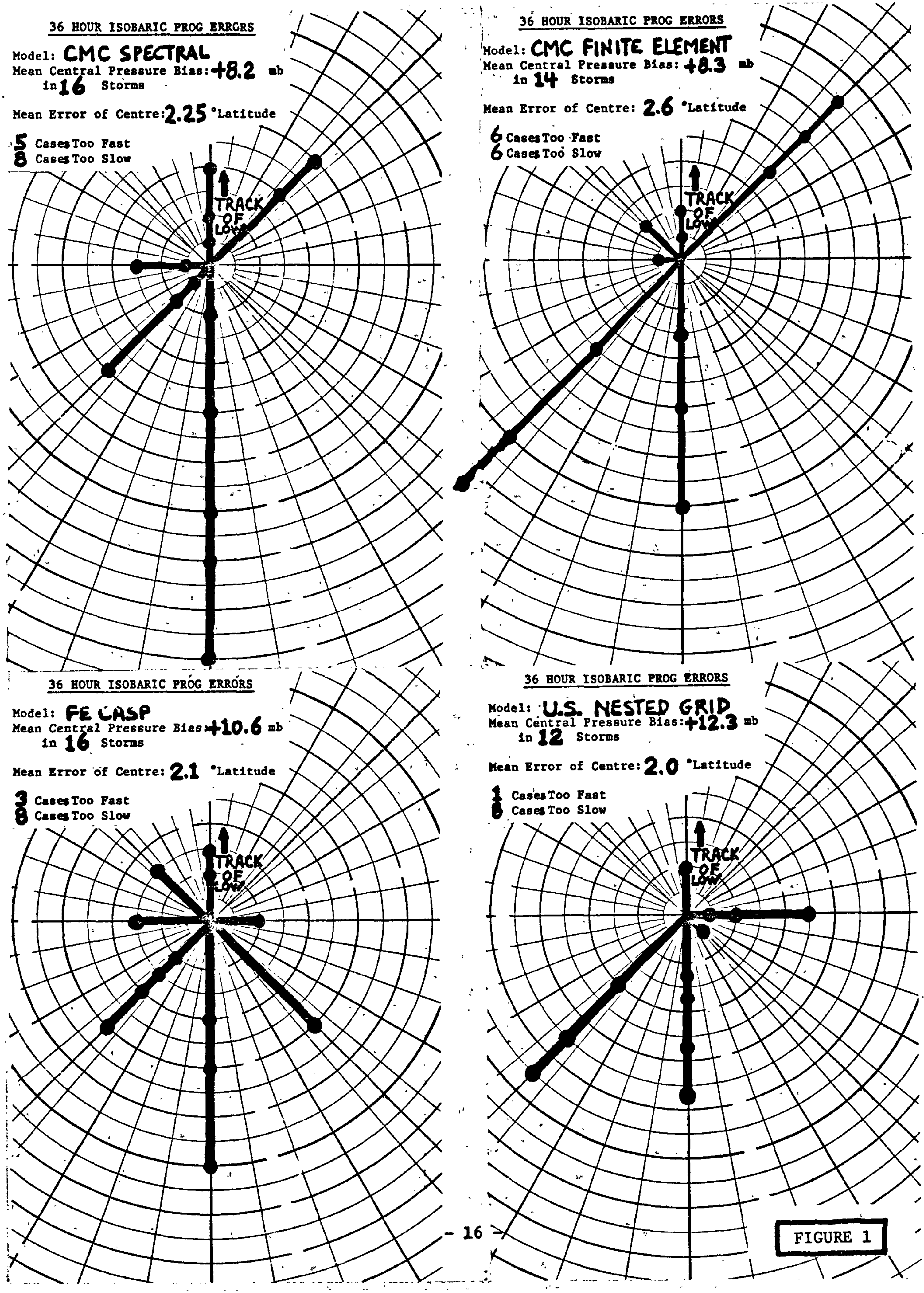

36 HOUR ISOBARIC PROG ERRORS
Model: CMC SPECTRAL
Mean Central Pressure Bias: +8.2 mb
in 16 Storms
Mean Error of Centre: 2.25 °Latitude
5 Cases Too Fast
8 Cases Too Slow
TRACK OF LOW
36 HOUR ISOBARIC PROG ERRORS
Model: CMC FINITE ELEMENT
Mean Central Pressure Bias: +8.3 mb
in 14 Storms
Mean Error of Centre: 2.6 °Latitude
6 Cases Too Fast
6 Cases Too Slow
TRACK OF LOW
36 HOUR ISOBARIC PROG ERRORS
Model: FE CASP
Mean Central Pressure Bias: +10.6 mb
in 16 Storms
Mean Error of Centre: 2.1 °Latitude
3 Cases Too Fast
8 Cases Too Slow
TRACK OF LOW
36 HOUR ISOBARIC PROG ERRORS
Model: U.S. NESTED GRID
Mean Central Pressure Bias: +12.3 mb
in 12 Storms
Mean Error of Centre: 2.0 °Latitude
1 Cases Too Fast
6 Cases Too Slow
TRACK OF LOW

FIGURE 1

AN EVALUATION OF MODEL PRECIPITATION FORECASTS

FOR STATIONS: YAW, WSA, YYT; FEB. 1 TO MAR. 15, 1986, ON DAYS (24HR ENDING 12Z) WHEN 5MM OR MORE PCPN FELL, WHICH MODEL QPF (12 TO 36HR AMOUNTS) WAS:

DRIEST	MODEL	WETTEST
9	FE-CASP	8
1	CMC FINITE ELEMENT	21
22	CMC SPECTRAL	0
4	UFS.. NGM	7

ON DAYS WHEN 5MM OR MORE PCPN FELL, WAS A GIVEN MODEL:

TOO DRY	MODEL	TOO WET
28	FE-CASP	4
22	CMC FINITE ELEMENT	11
32	CMC SPECTRAL	4
19	U.S. NGM	4

ON DAYS WHEN MEASUREABLE PCPN FELL OR WAS FORECASTED, WAS A GIVEN MODEL:

TOO DRY	MODEL	TOO WET
41	FE-CASP	19
30	CMC FINITE ELEMENT	48
53	CMC SPECTRAL	10
30	U.S. NGM	17

FIGURE 2

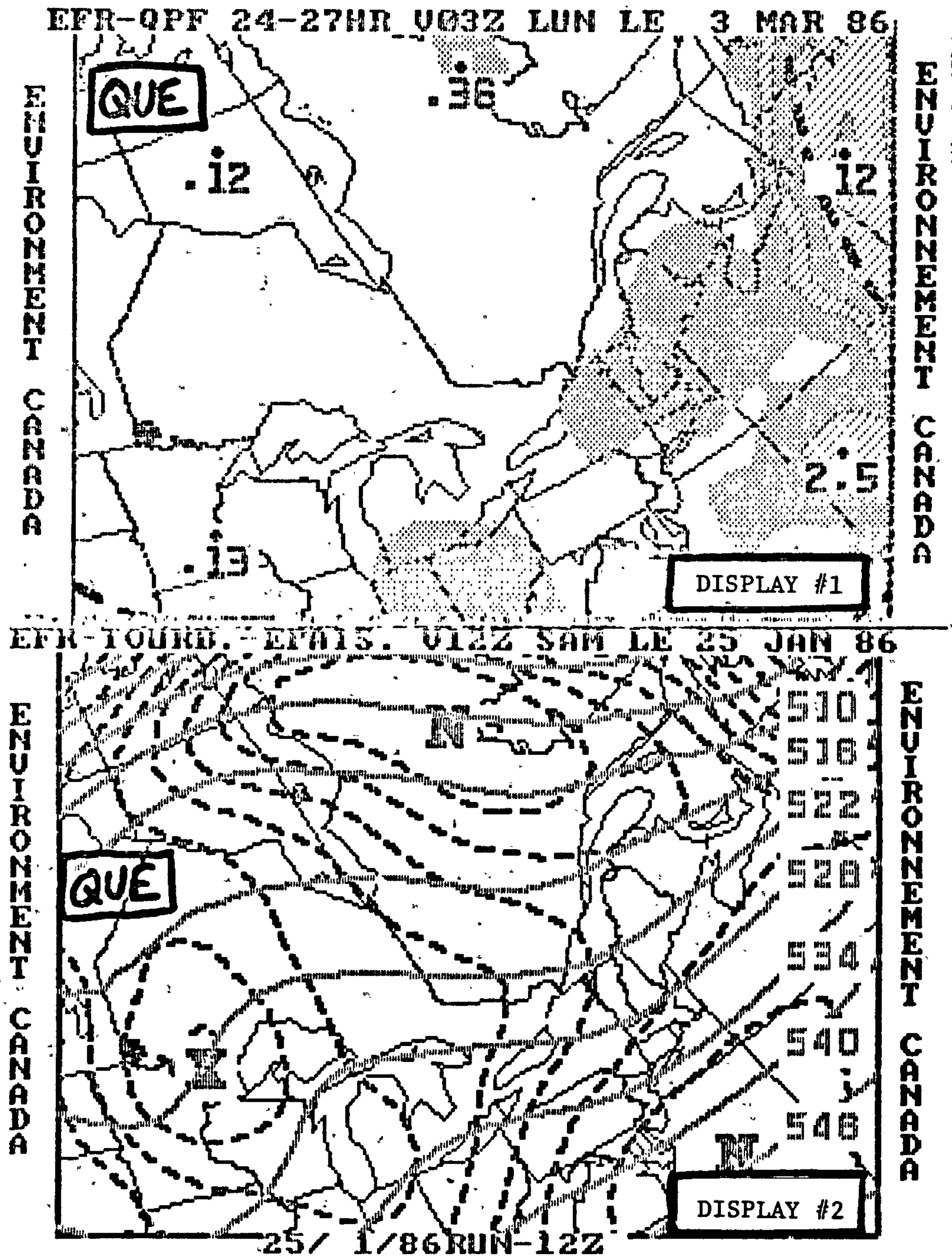

EFR-QPF 24-27HR V03Z LUN LE 3 MAR 86
QUE
.36
.12
.12
2.5
.13
DISPLAY #1
ENVIRONNEMENT CANADA
ENVIRONNEMENT CANADA
QUE
510
516
522
528
534
540
546
DISPLAY #2
25/ 1/86RUN-12Z
ENVIRONNEMENT CANADA
ENVIRONNEMENT CANADA

FIGURE 3A

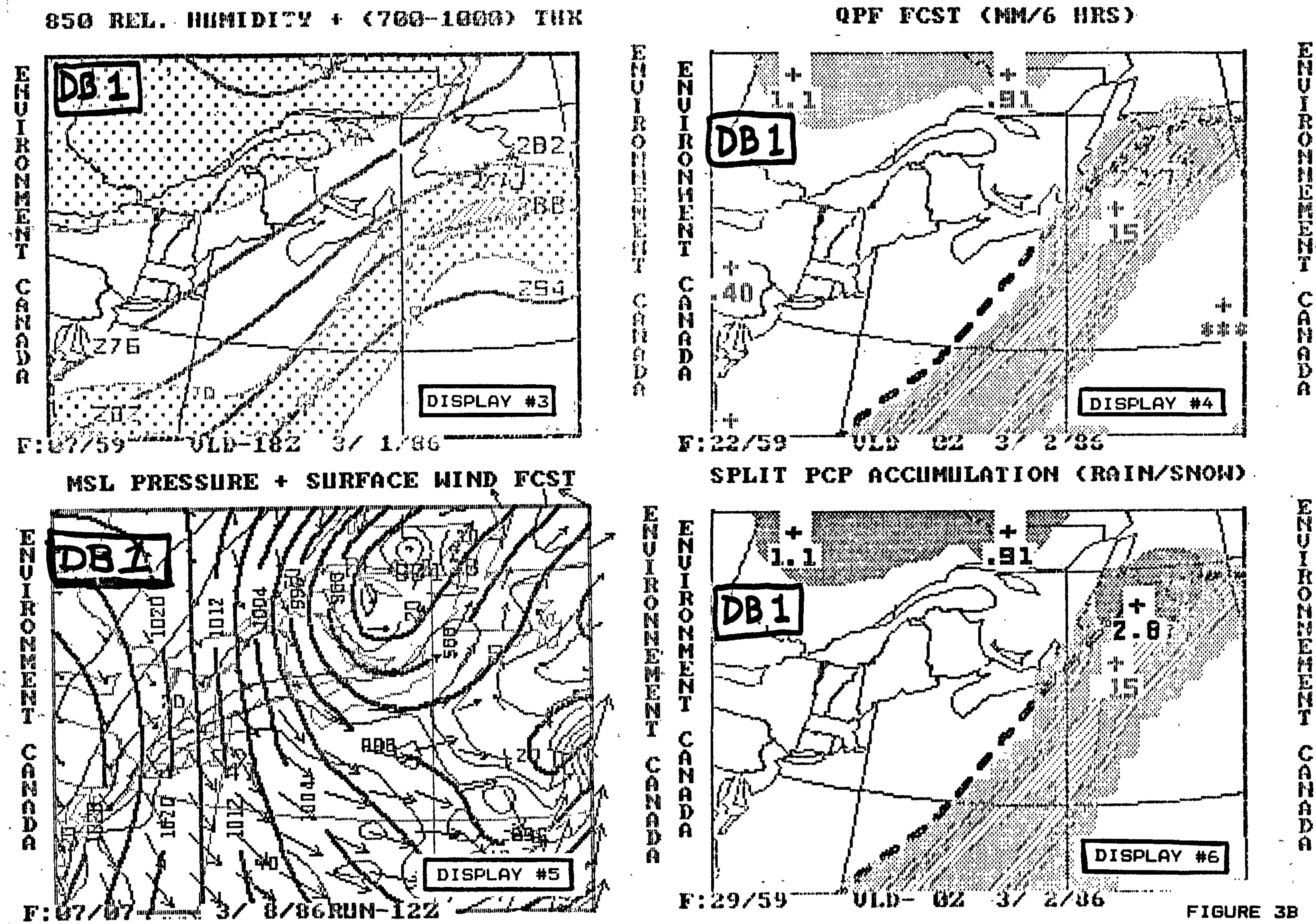

850 REL. HUMIDITY + (700-1000) THK
DB1
282
288
294
276
DISPLAY #3
F:07/59 VLD-18Z 3/ 1/86
ENVIRONMENT CANADA
QPF FCST (MM/6 HRS)
DB1
1.1
.91
15
.40
DISPLAY #4
F:22/59 VLD 0Z 3/ 2/86
ENVIRONMENT CANADA
MSL PRESSURE + SURFACE WIND FCST
DB1
1020
1012
1004
996
988
DISPLAY #5
F:07/07 3/ 8/86RUN-12Z
ENVIRONMENT CANADA
SPLIT PCP ACCUMULATION (RAIN/SNOW)
DB1
1.1
.91
2.8
15
DISPLAY #6
F:29/59 VLD- 0Z 3/ 2/86
ENVIRONMENT CANADA

FIGURE 3B

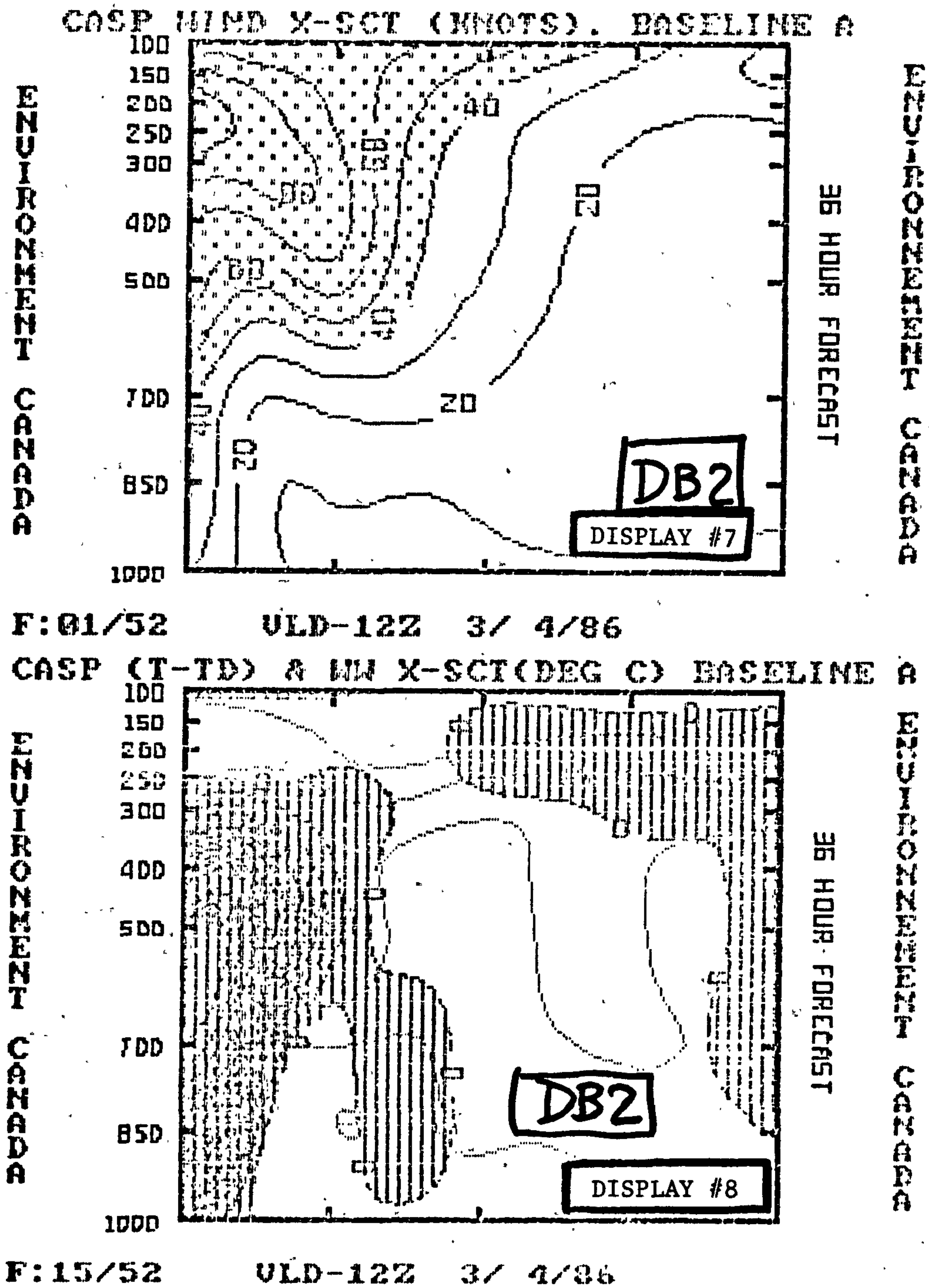
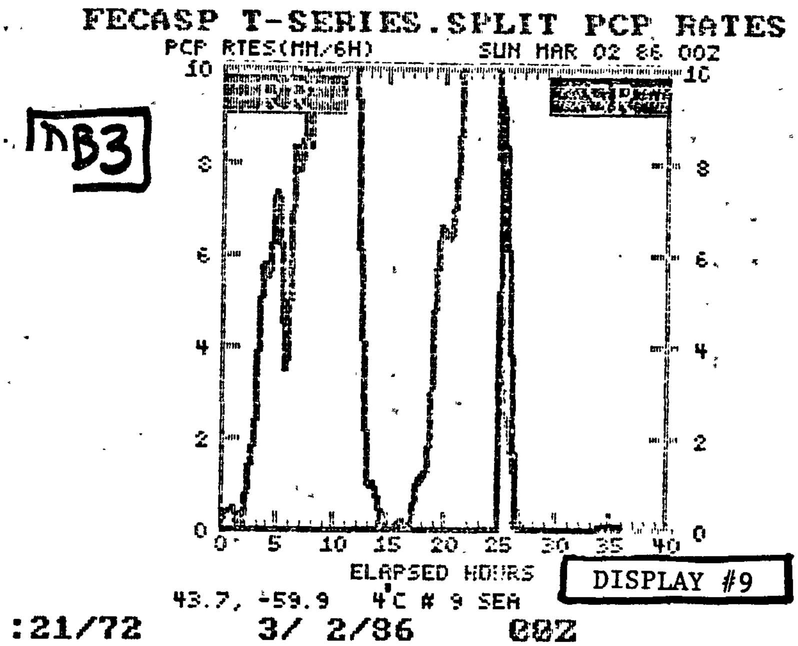
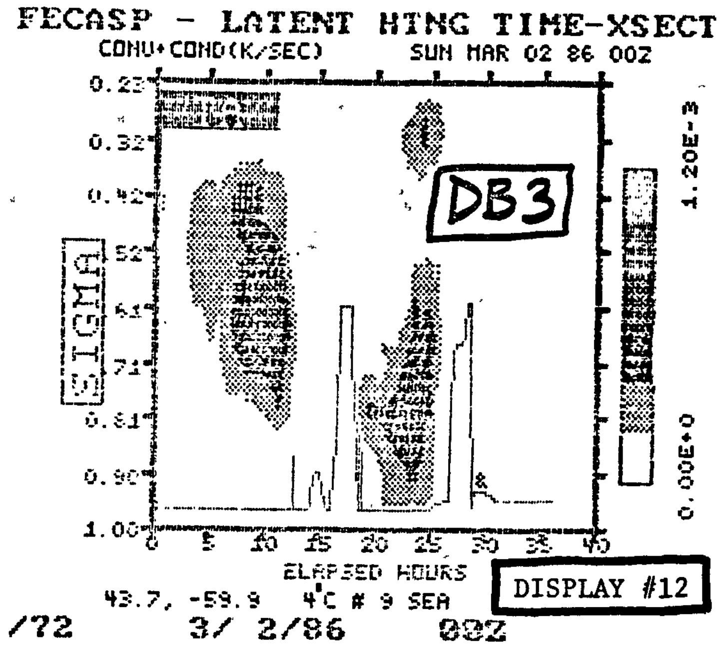
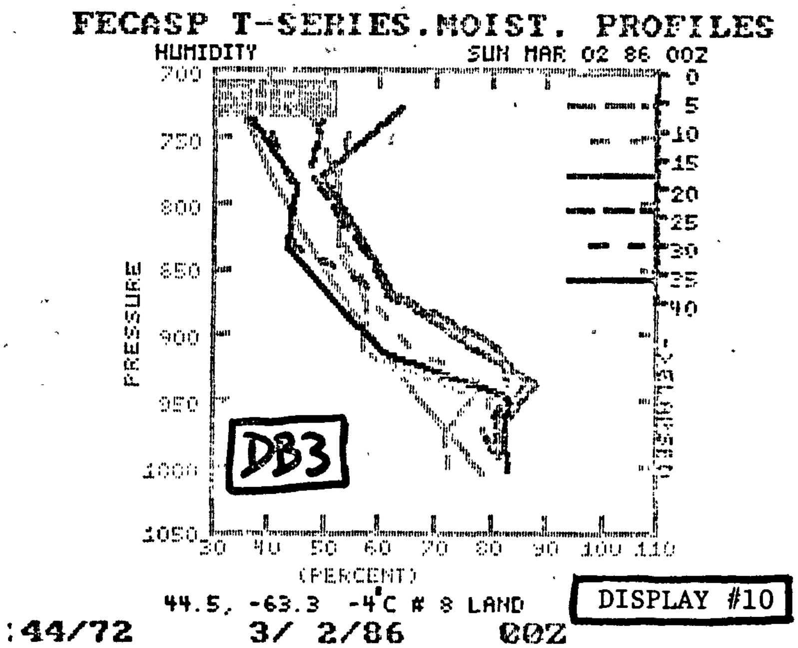
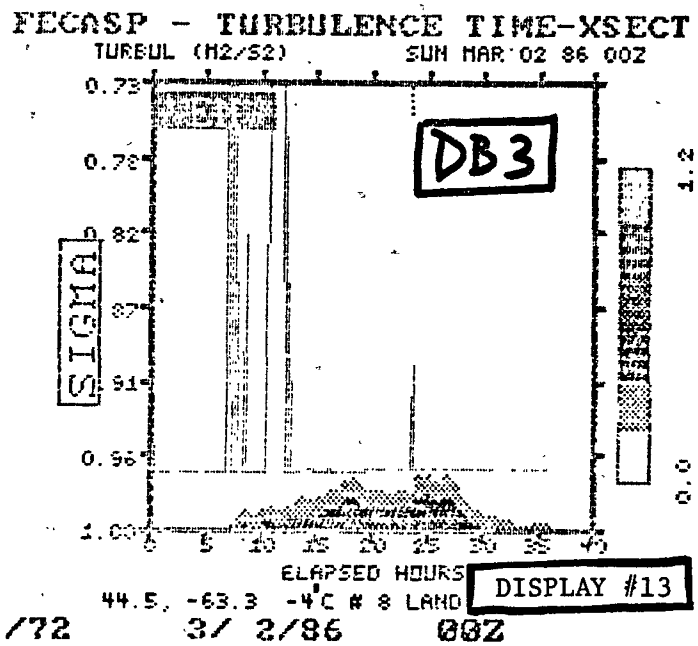

CASP WIND X-SCT (KNOTS). BASELINE A
100
150
200
250
300
400
500
700
850
1000
40
30
20
ENVIRONMENT CANADA
36 HOUR FORECAST
DB2
DISPLAY #7
F:01/52 VLD-12Z 3/ 4/86
CASP (T-TD) & WW X-SCT(DEG C) BASELINE A
100
150
200
250
300
400
500
700
850
1000
ENVIRONMENT CANADA
36 HOUR FORECAST
DB2
DISPLAY #8
F:15/52 VLD-12Z 3/ 4/86

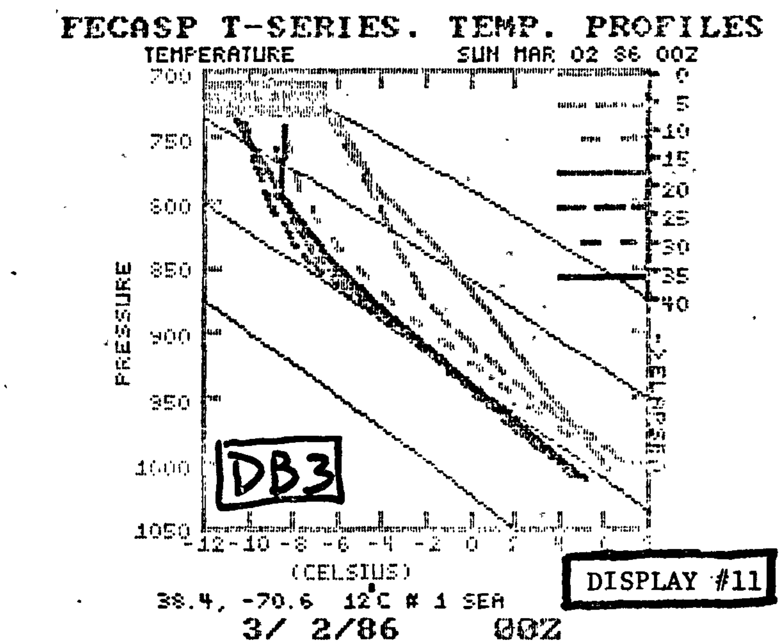
FIGURE 3C


FECASP T-SERIES.SPLIT PCP RATES
PCP RTES(MM/6H)
SUN MAR 02 86 00Z
DB3
ELAPSED HOURS
DISPLAY #9
43.7, -59.9 4°C # 9 SEA
:21/72 3/ 2/86 00Z


FECASP - LATENT HTNG TIME-XSECT
CONV+COND(K/SEC)
SUN MAR 02 86 00Z
SIGMA
DB3
1.20E-3
0.00E+0
ELAPSED HOURS
DISPLAY #12
43.7, -59.9 4°C # 9 SEA
/72 3/ 2/86 00Z


FECASP T-SERIES.MOIST. PROFILES
HUMIDITY
SUN MAR 02 86 00Z
PRESSURE
DB3
(PERCENT)
ELAPSED
DISPLAY #10
44.5, -63.3 -4°C # 8 LAND
:44/72 3/ 2/86 00Z


FECASP - TURBULENCE TIME-XSECT
TURBUL (M2/S2)
SUN MAR 02 86 00Z
SIGMA
DB3
1.2
0.0
ELAPSED HOURS
DISPLAY #13
44.5, -63.3 -4°C # 8 LAND
/72 3/ 2/86 00Z


FECASP T-SERIES. TEMP. PROFILES
TEMPERATURE
SUN MAR 02 86 00Z
PRESSURE
DB3
(CELSIUS)
ELAPSED
DISPLAY #11
38.4, -70.6 12°C # 1 SEA
3/ 2/86 00Z

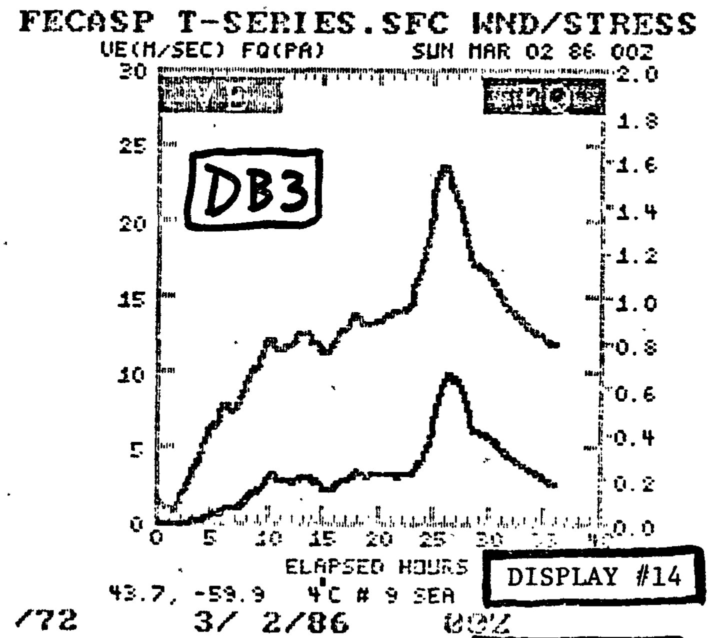

FECASP T-SERIES.SFC WND/STRESS
VE(M/SEC) FQ(PA)
SUN MAR 02 86 00Z
DB3
ELAPSED HOURS
DISPLAY #14
43.7, -59.9 4°C # 9 SEA
/72 3/ 2/86 00Z

FIGURE 3D

ENVIRONMENT CANADA

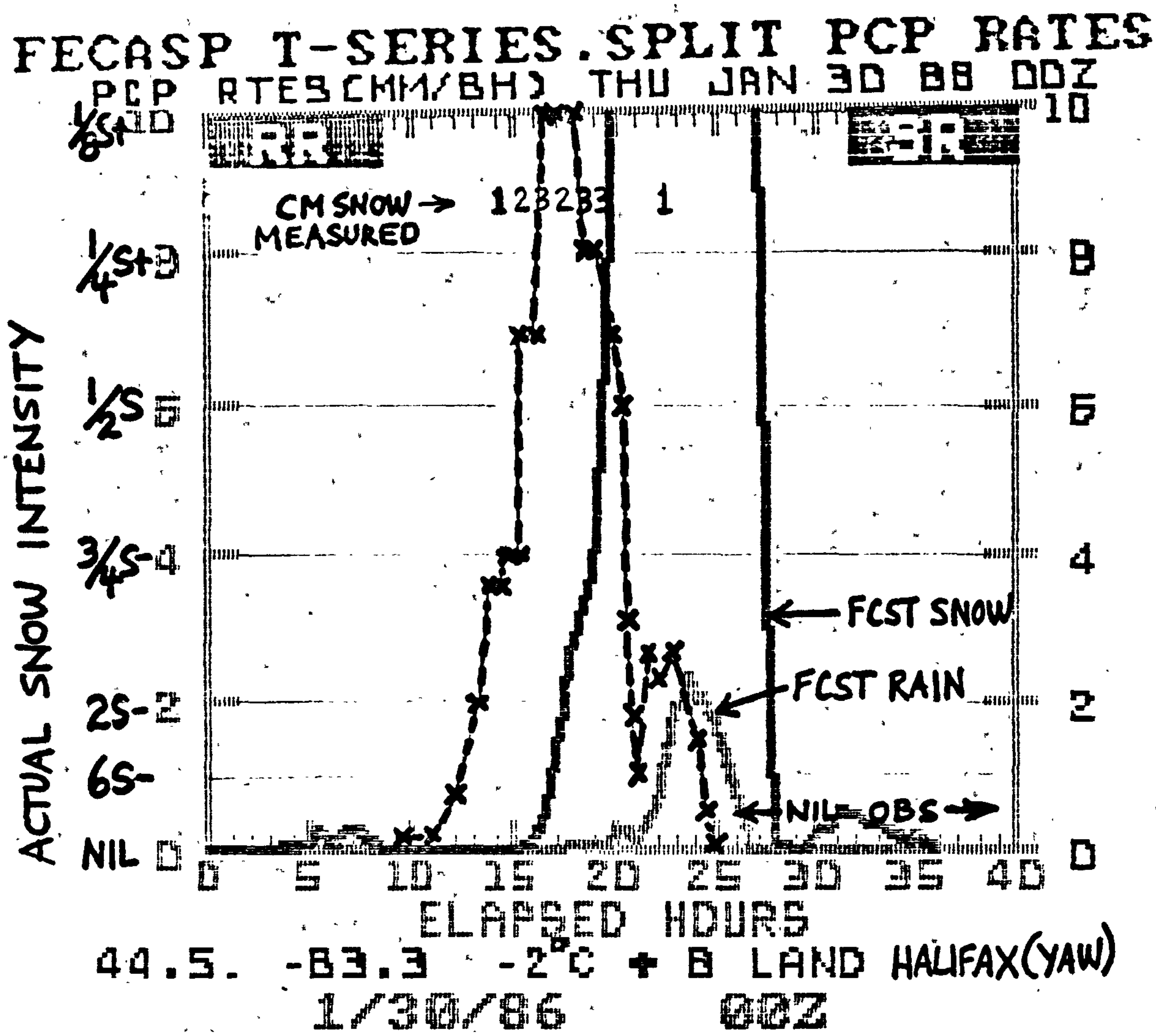


Figure 4A - Time Series Split Precipitation Rates

Shearwater, Time Zero = 0000Z 30 Jan. 1986

The "FE-CASP" Model forecast rain mixed with the general snowfall as a deepening low passed 3 degrees south of Halifax (YAW) late on January 30. Actual precipitation was all snow. This error was typical of the model just north of the surface low centre or frontal wave. (See 3.4.1 C).

The onset of snow was forecast 4 hours late and the end 7 hours late at Halifax. This was attributed to the system moving 3 degrees latitude (180 nautical miles) faster in 36 hours than forecast.

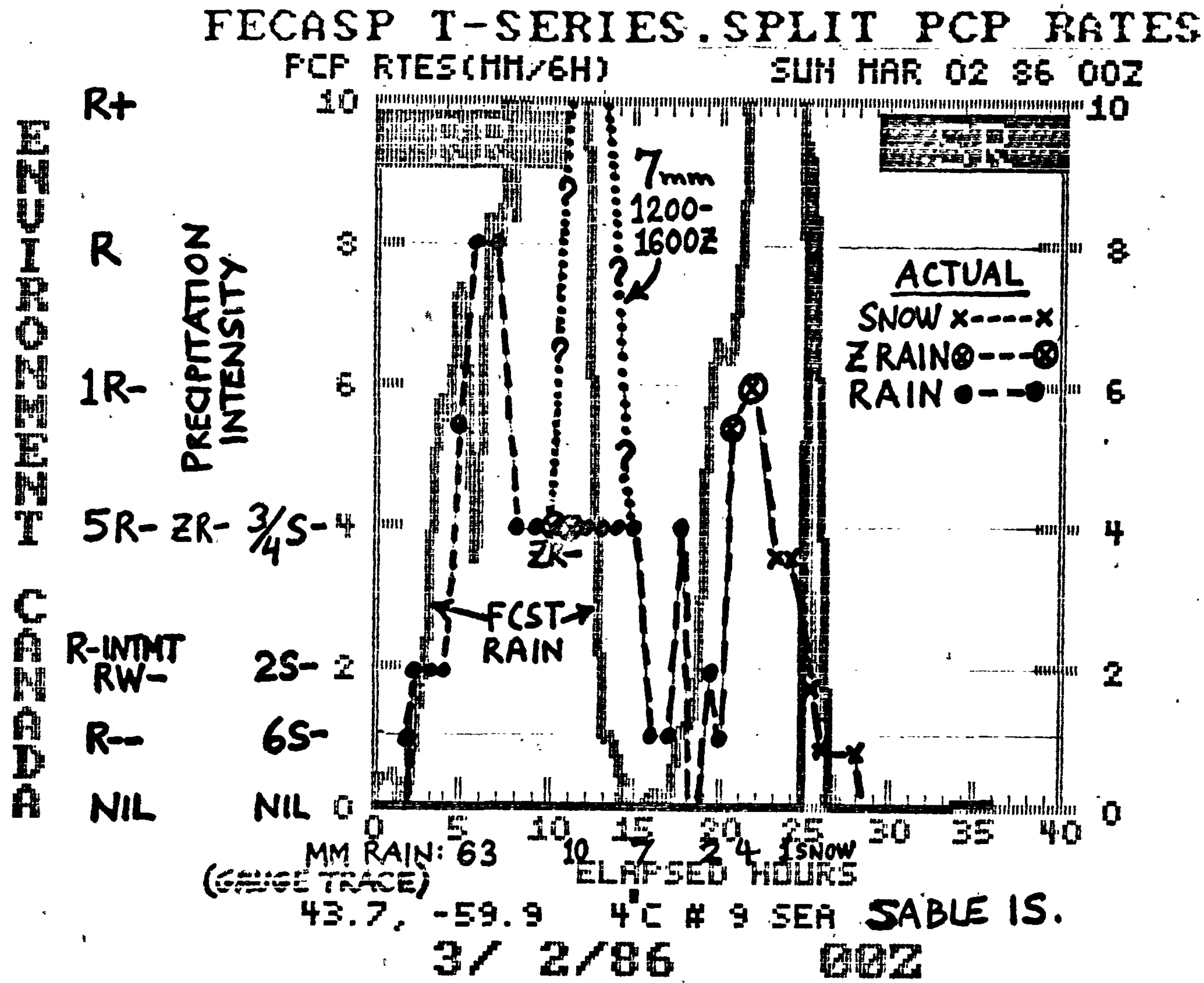


Figure 4B - Time Series Split Precipitation Rates

Sable Island, Time Zero = 0000Z 2 Mar 1986

The rain actually began about 02Z on March 2nd as forecast. This rain was reported as RW- in the "SA" hourlies. Because of low-level cooling the rain was "freezing" at 10Z and 11Z. Significant accumulations of rain apparently continued until at least 16Z, March 2, judging by accumulations from gauge traces noted intermittently on 'SA' reports. These accumulations are noted horizontally below the 'Time' co-ordinate. The dotted 'question mark' line is intended to suggest that the rain rate was likely higher than the good visibility criterion indicated. The pale grey forecast rain rate trace changes to a dark grey snow rate about March 3 01Z (at hour 25). This changeover is only 1 to 2 hours later than actually occurred with one mile visibility in light snow observed at 23Z and 00Z. In this case the onset of rain, the significant rates from about 04Z to 12Z, the very light period about 15 to 18Z, the second heavier period about 22Z to 24Z and the immediate change to snow and end of snow were all quite well forecast.

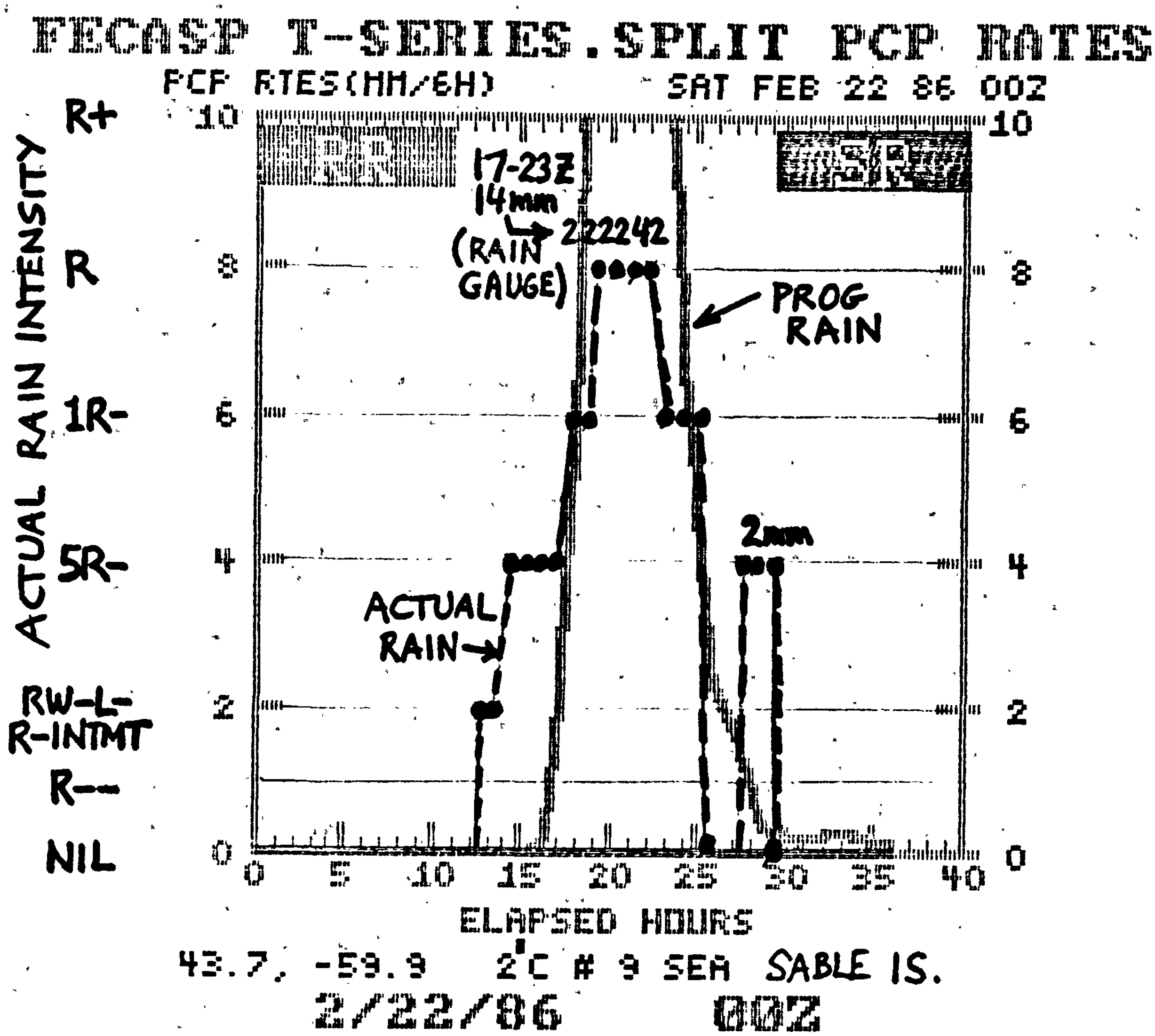
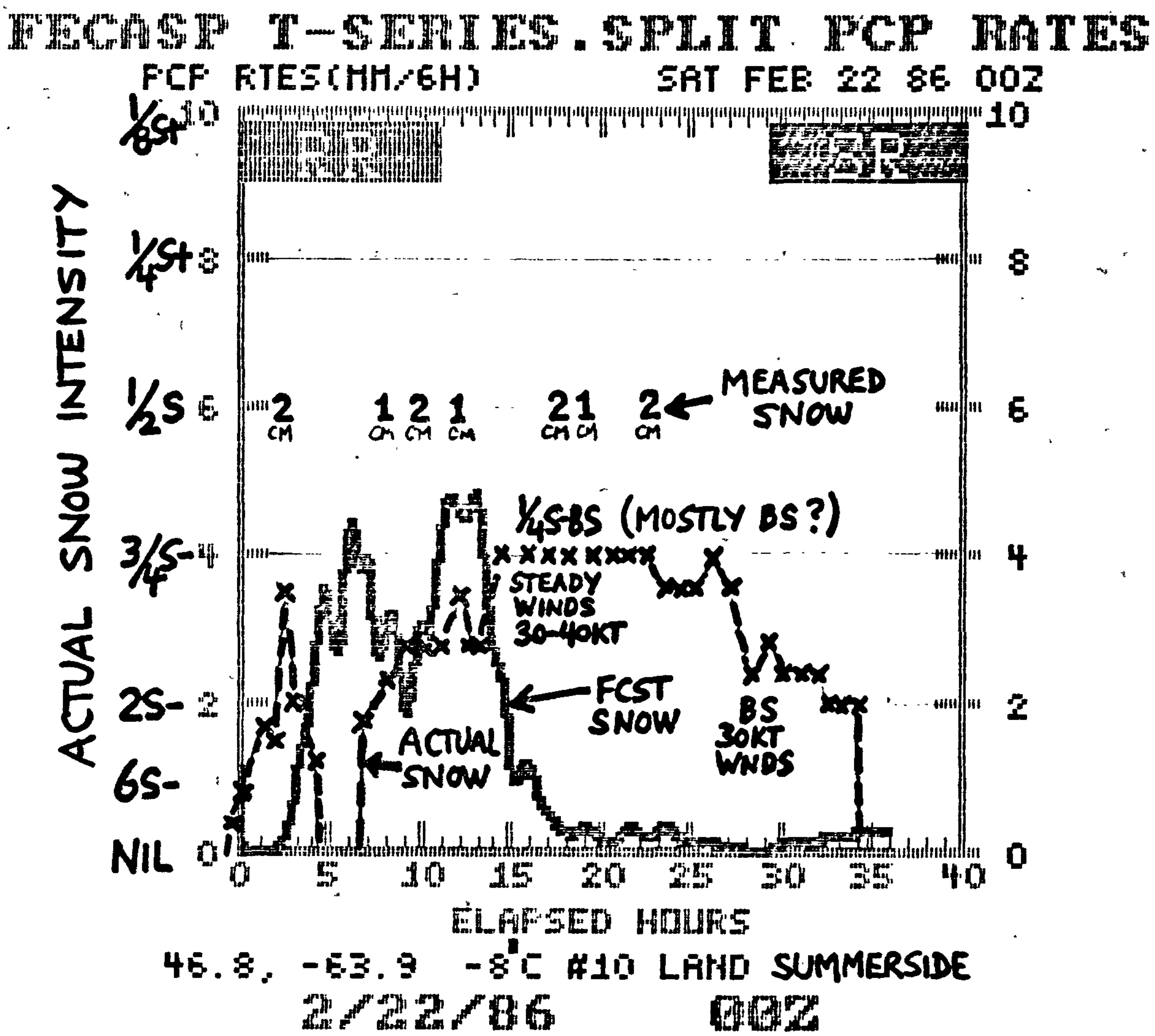


Figure 4C - Time Series Split Precipitation Rates

Sable Island, Time Zero = 0000Z 22 Feb. 1986

Although the actual rain was reported as starting before 13Z, reported accumulation didn't begin until about 17Z. This fits the forecast onset of rain quite well. The end of continuous rain at about 01Z of Day 2 was very well forecast. Even the 2 mm which fell 2 to 4 hours later was suggested by the gradual slope to the forecast rain trace from 25 to 30 hours after 'time zero'.



ENVIRONMENT CANADA

Figure 4D - Time Series Split Precipitation Rates
Summerside, Time Zero = 0000Z 22 Feb. 1986

All numerical models were slow in forecasting motion of this storm and thus it is not surprising that snow actually started 2 or 3 hours before it was predicted. It is interesting to note that the actual break in snow about 05-06Z is reflected as a forecast minimum at 08-09Z.

Winds at Summerside (YSU) remained under 10 knots until 12Z, then jumped to 30 knots from 14Z onwards. The remarkable jump in wind speed was accompanied by lowered visibilities and an additional 5 cm. snow measurement over an 8 hour period up to 22Z. The forecast, however, showed snowfall virtually ending by 15-16Z. In this case there is a suspicion that the forecast snowfall rate may have been more accurate than the observations. (3.4.1 a) and h).

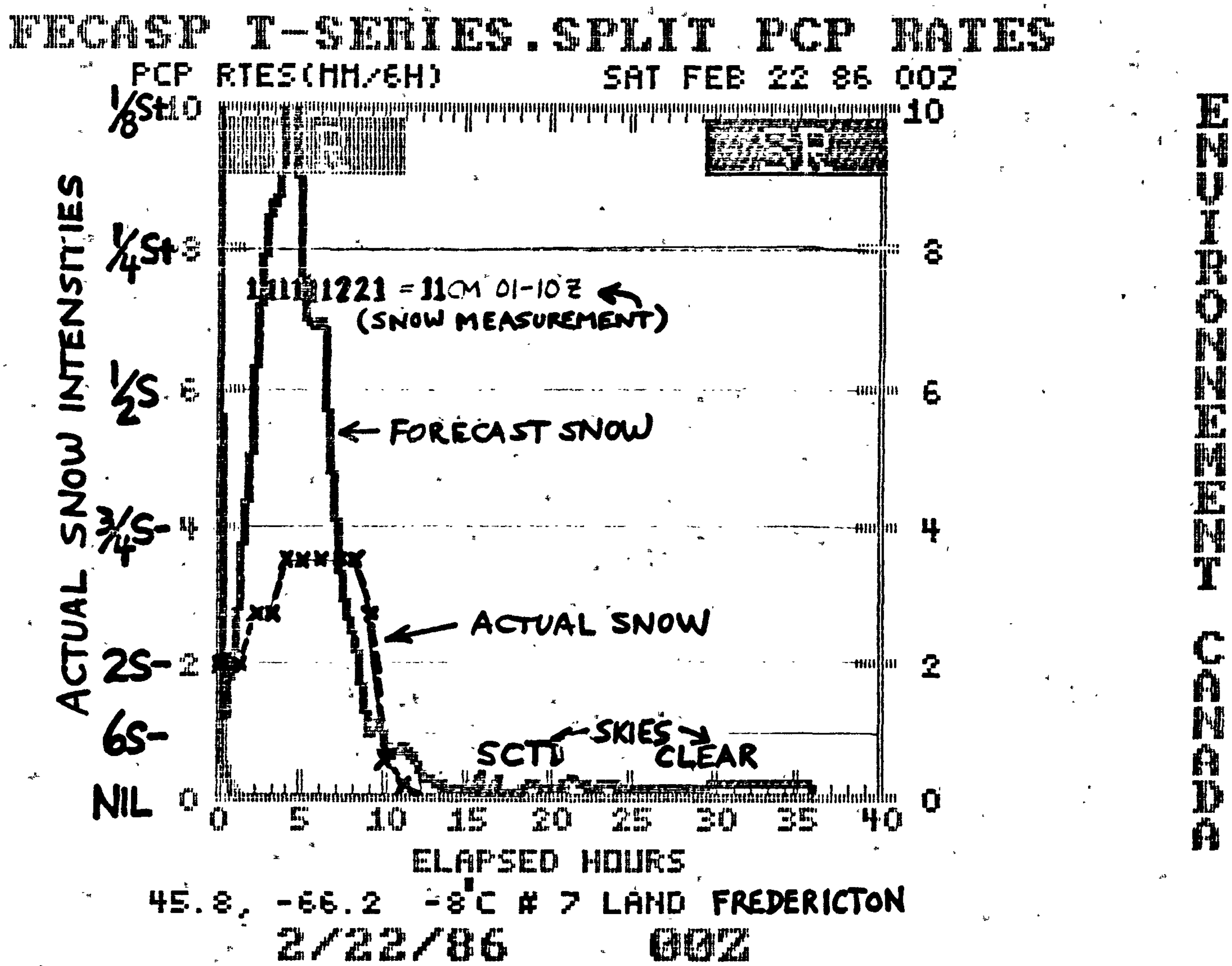


Figure 4E - Time Series Split Precipitation Rates
Fredericton, Time Zero = 0000Z 22 Feb. 1986

The snow was well forecast in this case albeit early in the time period. An integration of the precipitation rate over the first 10 hours of the forecast would yield approximately 15 mm (15 cm snow) which fits the observed data well. It is questionable why visibilities overnight never fell below one mile even though 11 cm of snow was observed to fall in 9 hours.

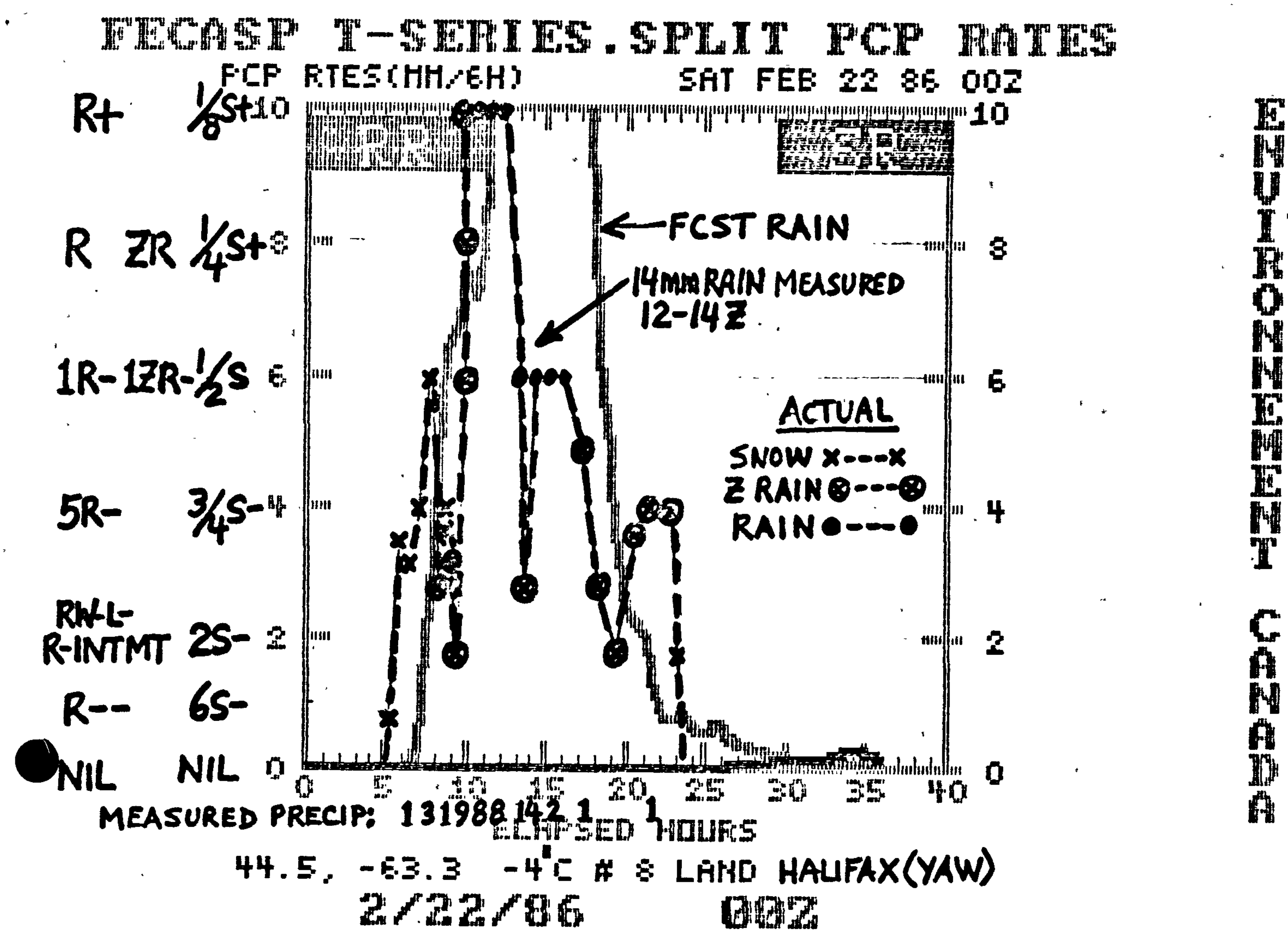
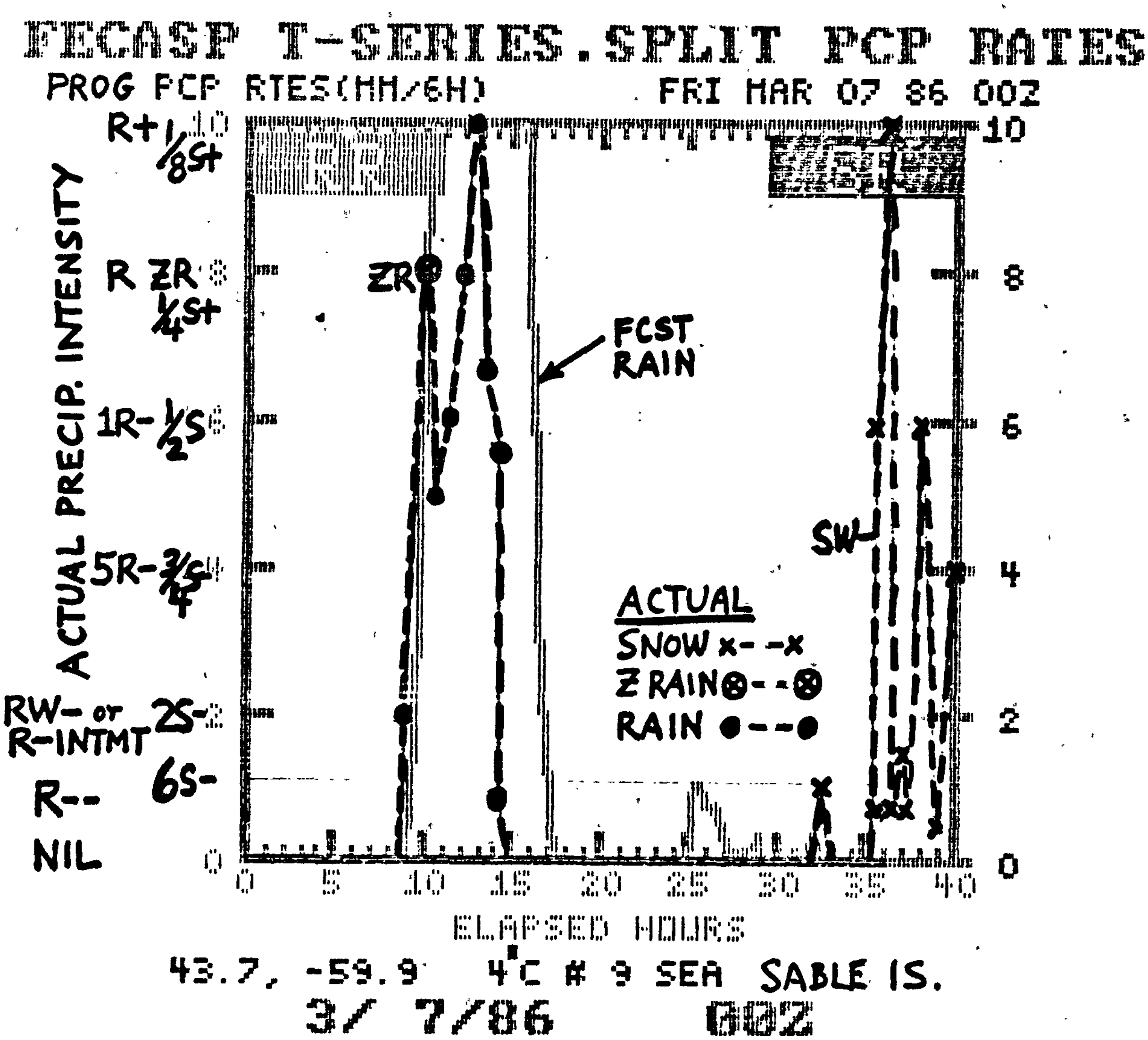


Figure 4F - Time Series Split Precipitation Rates

Shearwater, Time Zero = 0000Z 22 Feb. 1986

The 'FE-CASP' model did not forecast the occurrence of snow at the onset of this rainstorm and the brief period of snow at the end was forecast much too late. This model does not attempt to discriminate between rain and freezing rain.

The moderate to heavy rain which fell between 09Z and 14Z (39 mm) was forecast about 3 hours too slow, but the intensity seemed good. It is unfortunate that the forecast rate was off scale for 6 hours. (See 3.4.1 e)).



ENVIRONMENT CANADA

Figure 4G - Time Series Split Precipitation Rates

Sable Island - Time Zero = 0000Z 07 Mar. 1986

The onset of rain was forecast very well but it was predicted to persist 2 hours too long. The duration of precipitation was a little too long in most 'FE-CASP' forecasts. (Eg. Figures 4A and 4K).

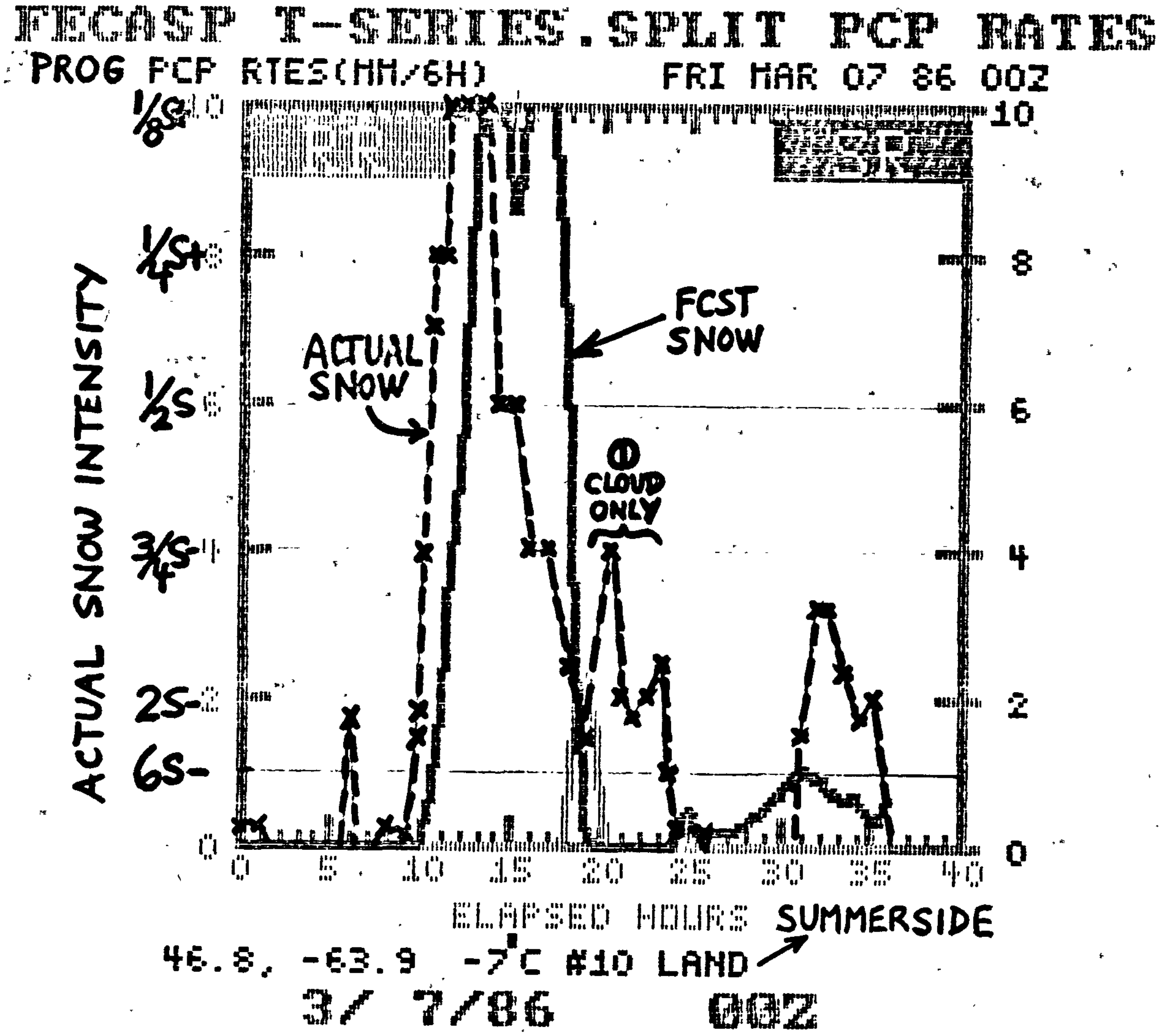


Figure 4H - Time Series Split Precipitation Rates
Summerside, Time Zero = 0000Z 07 Mar. 1986

The heavier snow began and ended (as usual) a little sooner than forecast. (The 36-hour 'FE-CASP' forecast of the related surface low was 2 to 3 degrees latitude slow). The actual track of the surface low crossed Eastern Prince Edward Island. In this case, the 'FE-CASP' model (as usual) forecast some rain to become mixed with the snow near the tip of the warm sector, but no rain actually developed. (See 3.4.1 C)).

The occasional periods of light snow occurring after 24 hours were forecast, although the timing was understandably imprecise toward the end of the forecast period. Between 19 and 24 hours from initial time the actual snowfall rate estimated from visibility observations is probably too high as cloud was reported as scattered. Thus, the insignificant forecast rate during this period is probably reasonable.

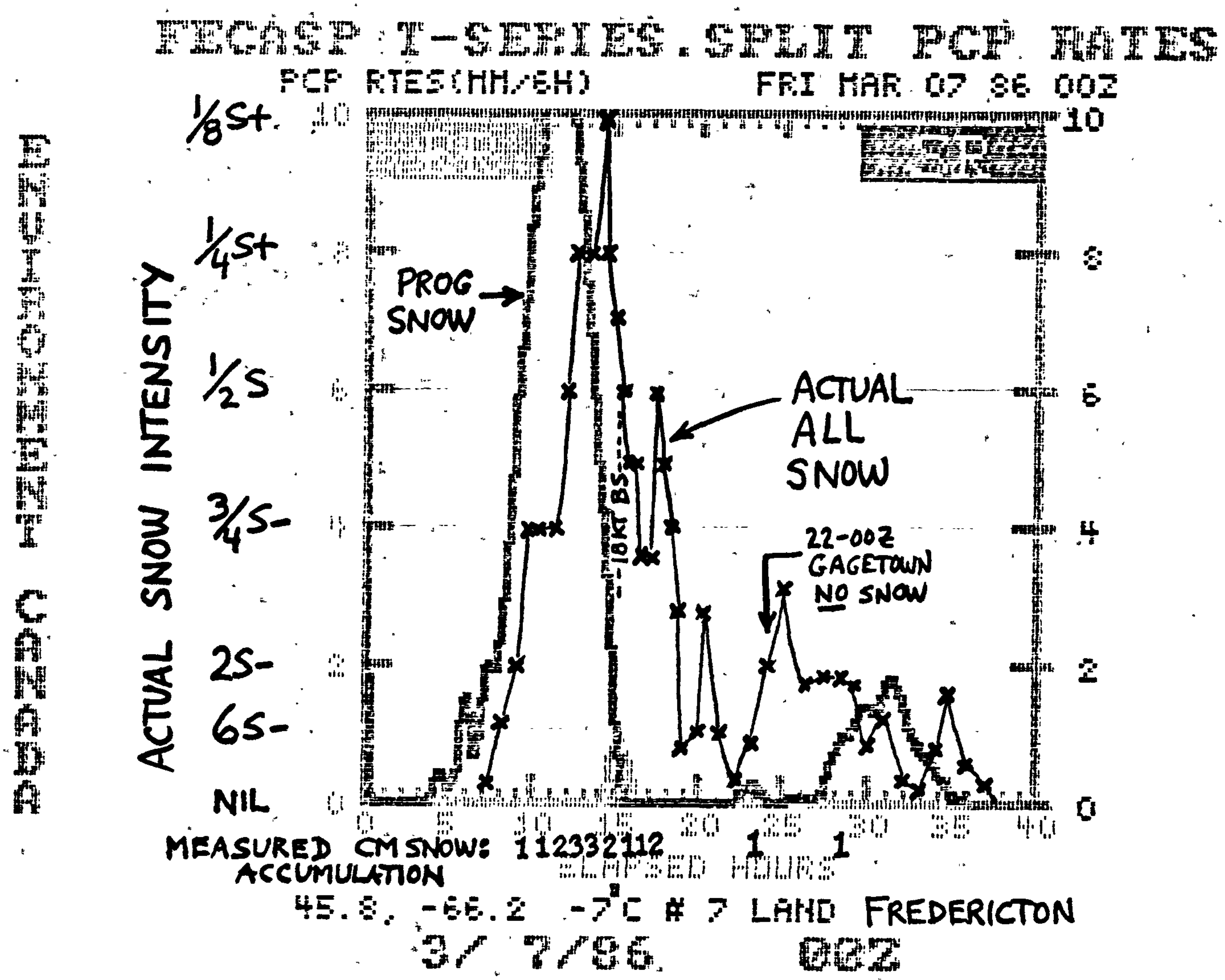


Figure 4I - Time Series Split Precipitation Rates

Fredericton, Time Zero = 0000Z 07 Mar. 1986

The snow arrived later than forecast in Fredericton on March 7. This unusual situation is probably related to a secondary centre developing southwest of Nova Scotia and the resultant slowing and weakening of the primary (old) centre in the St. Lawrence Valley more quickly than forecast. The passage of snow associated with the weakening primary low is both forecast and observed from 24 to 36 hours although the timing is imprecise as would be expected in such a delicate synoptic situation.

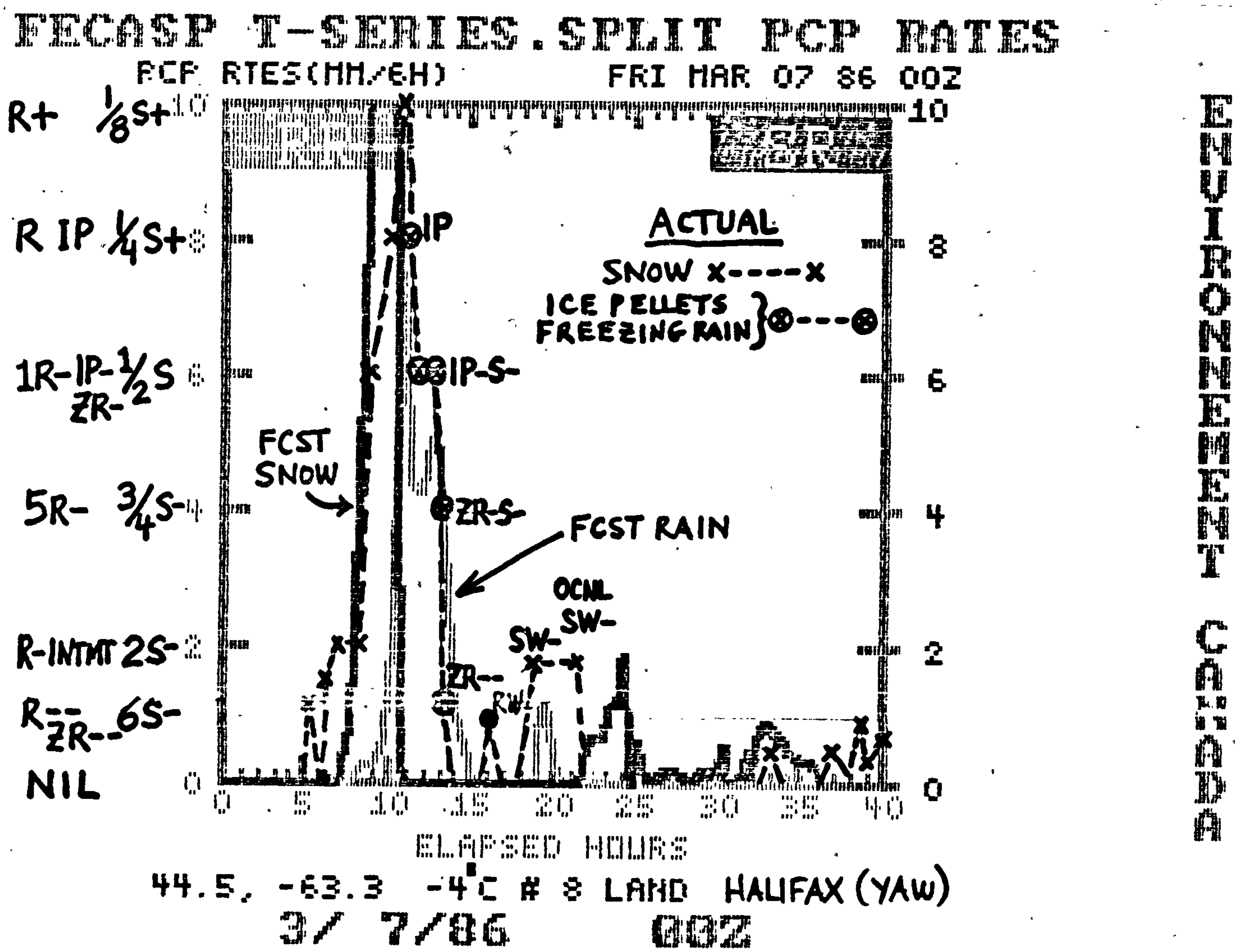


Figure 4J - Time Series Split Precipitation Rates

Shearwater, Time Zero = 0000Z 07 Mar. 1986

This appears to have been an outstanding forecast in terms of start and end of major precipitation and especially in terms of change from snow to forms of liquid precipitation at 10-11Z. (Presumably ice pellets (IP) count as rain in the 'FE-CASP' split precipitation rates).

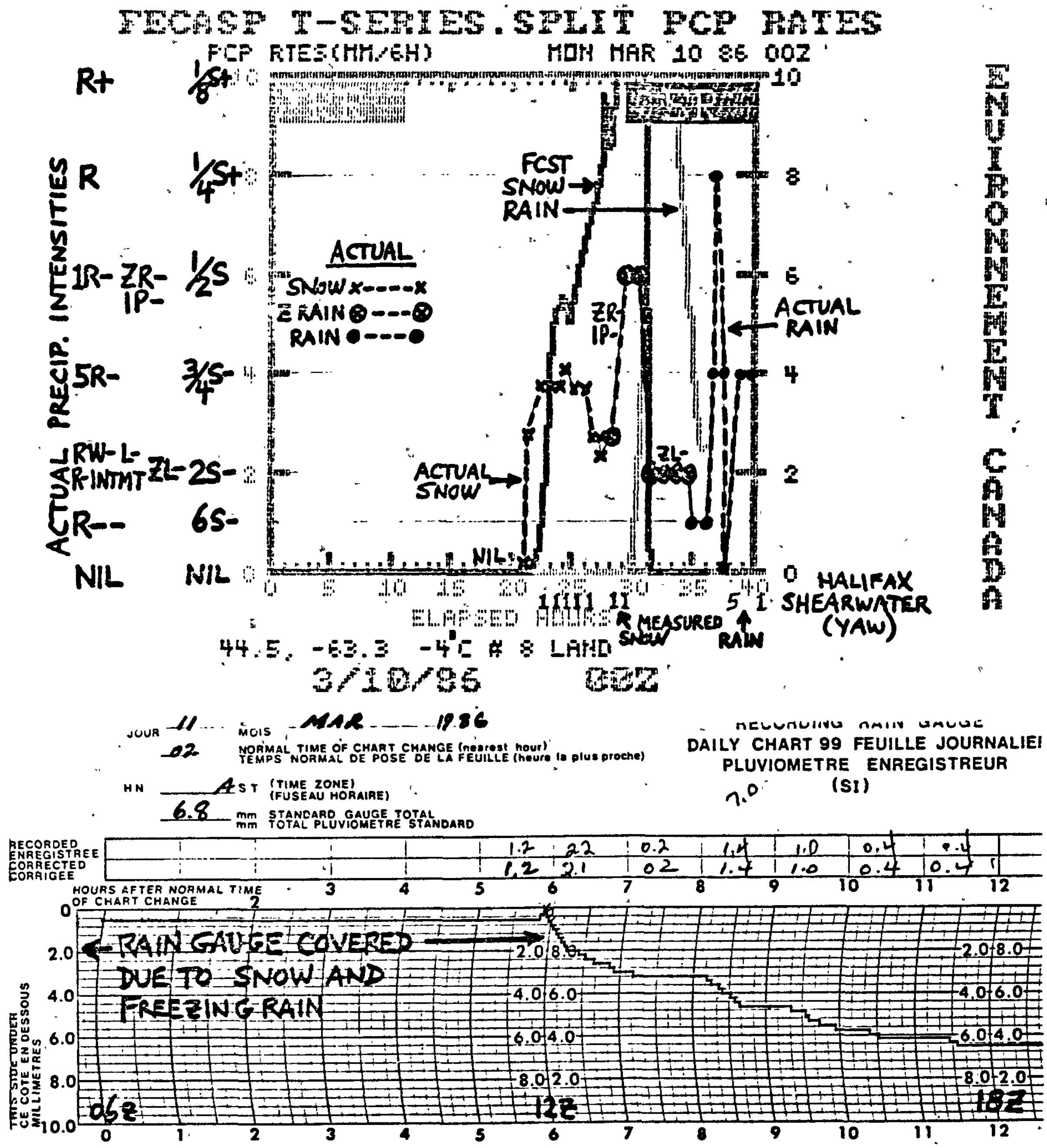
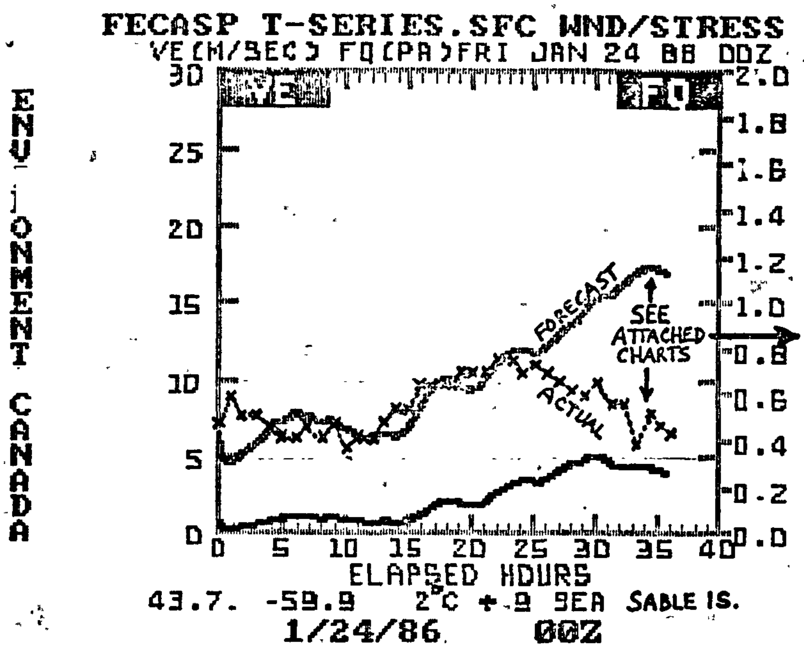


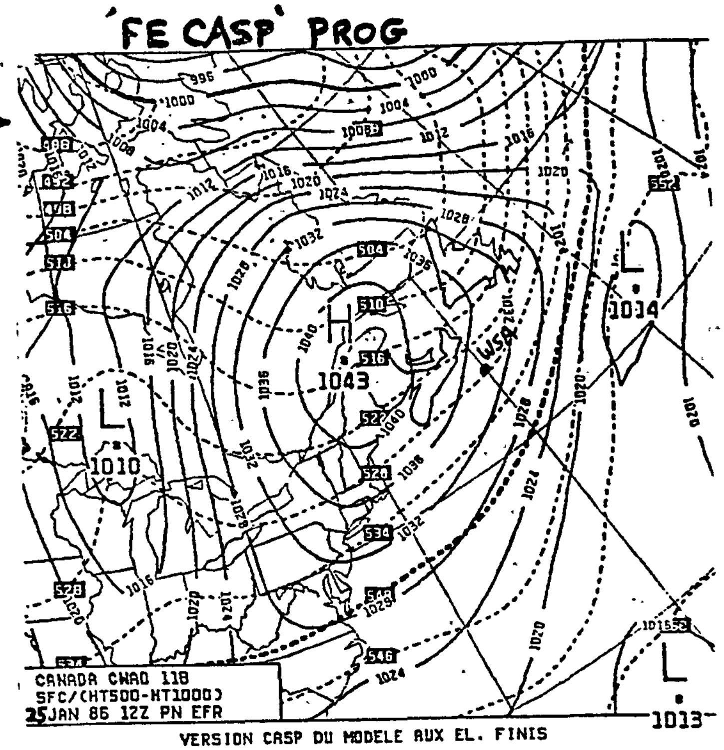
Figure 4K - Time Series Split Precipitation Rates

Shearwater, Time Zero = 0000Z 10 Mar. 1986

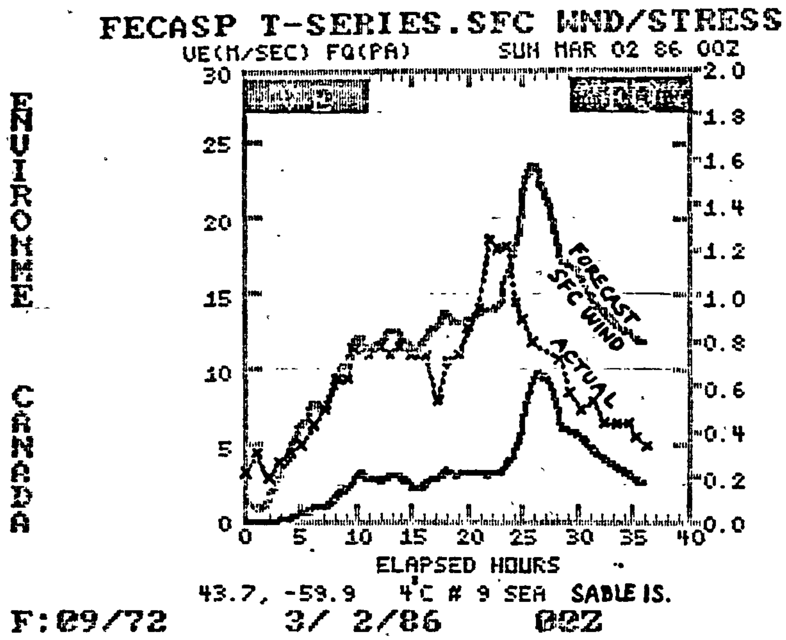
The lateness of the forecast onset of snow (by 2 hrs), the change to liquid forms (by 3 hrs) and the end of rain (by 4-5 hrs) seems to increase with time. The rain which occurred from 35 to 40 hrs after initial time is, of course, beyond the 36 hour forecast range in such circumstances. The Halifax (Shearwater YAW) rain gauge trace illustrates the great difficulty in verifying forecasts of mixed precipitation. (See 3.4.1 g)). It also confirms the showery rain which fell after 36 hours from initial time (ie. after Mar 11 1200Z).



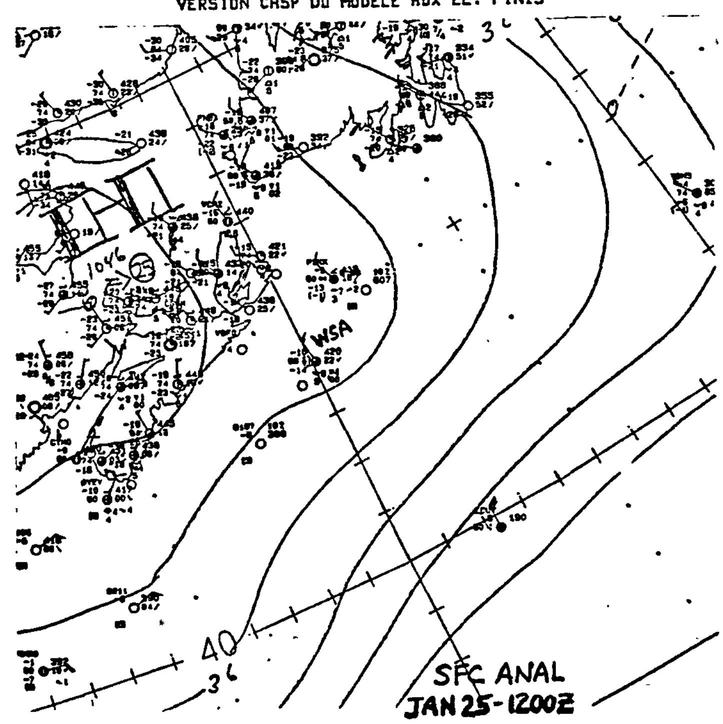
ENVIRONMENT CANADA
FECASP T-SERIES.SFC WND/STRESS
VE(M/SEC) FQ(PA) FRI JAN 24 88 00Z
VE
FQ
FORECAST
ACTUAL
SEE ATTACHED CHARTS
ELAPSED HOURS
43.7, -59.9 2°C + 9 SEA SABLE IS.
1/24/86 00Z



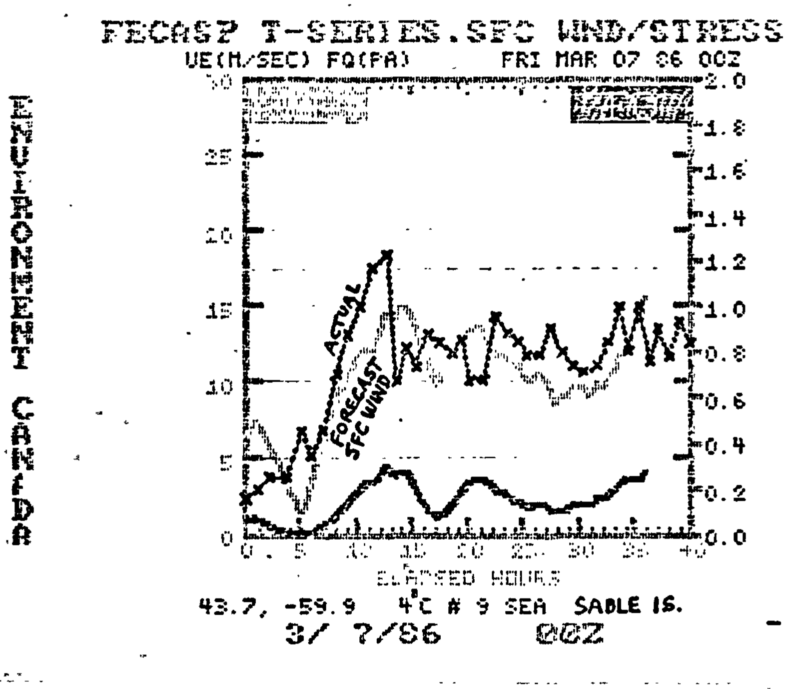
'FE CASP' PROG
1043
1010
1014
1013
WSA
CANADA CWAO 118
SFC/(HT500-HT1000)
25JAN 86 12Z PN EFR
VERSION CASP DU MODELE AUX EL. FINIS



ENVIRONNEMENT CANADA
FECASP T-SERIES.SFC WND/STRESS
VE(M/SEC) FQ(PA) SUN MAR 02 86 00Z
FORECAST SFC WIND
ACTUAL
ELAPSED HOURS
43.7, -59.9 4°C # 9 SEA SABLE IS.
F:09/72 3/ 2/86 00Z



WSA
1046
40
SFC ANAL
JAN 25-1200Z



ENVIRONNEMENT CANADA
FECASP T-SERIES.SFC WND/STRESS
VE(M/SEC) FQ(PA) FRI MAR 07 86 00Z
ACTUAL
FORECAST SFC WIND
ELAPSED HOURS
43.7, -59.9 4°C # 9 SEA SABLE IS.
3/ 7/86 00Z

FIGURE 5

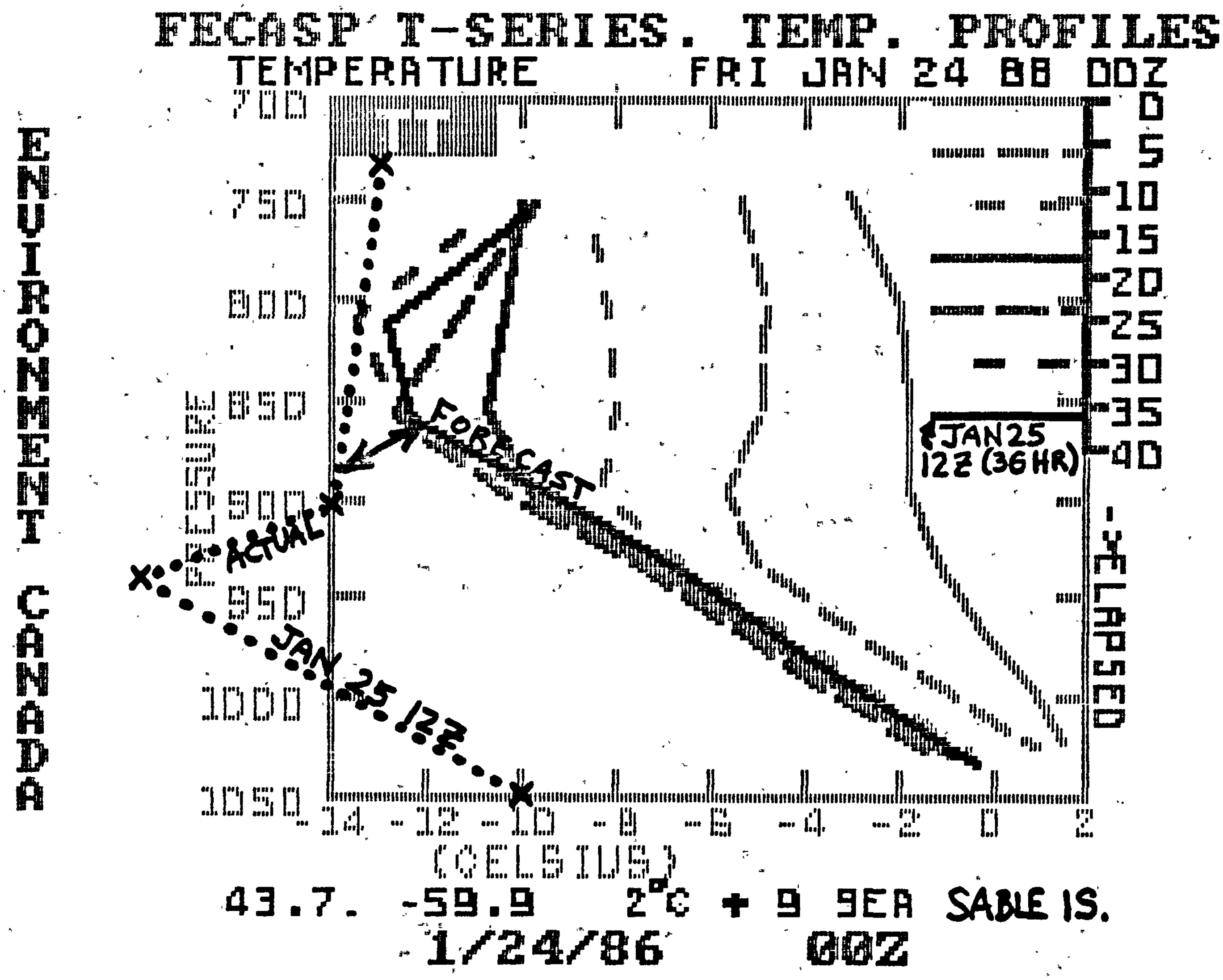
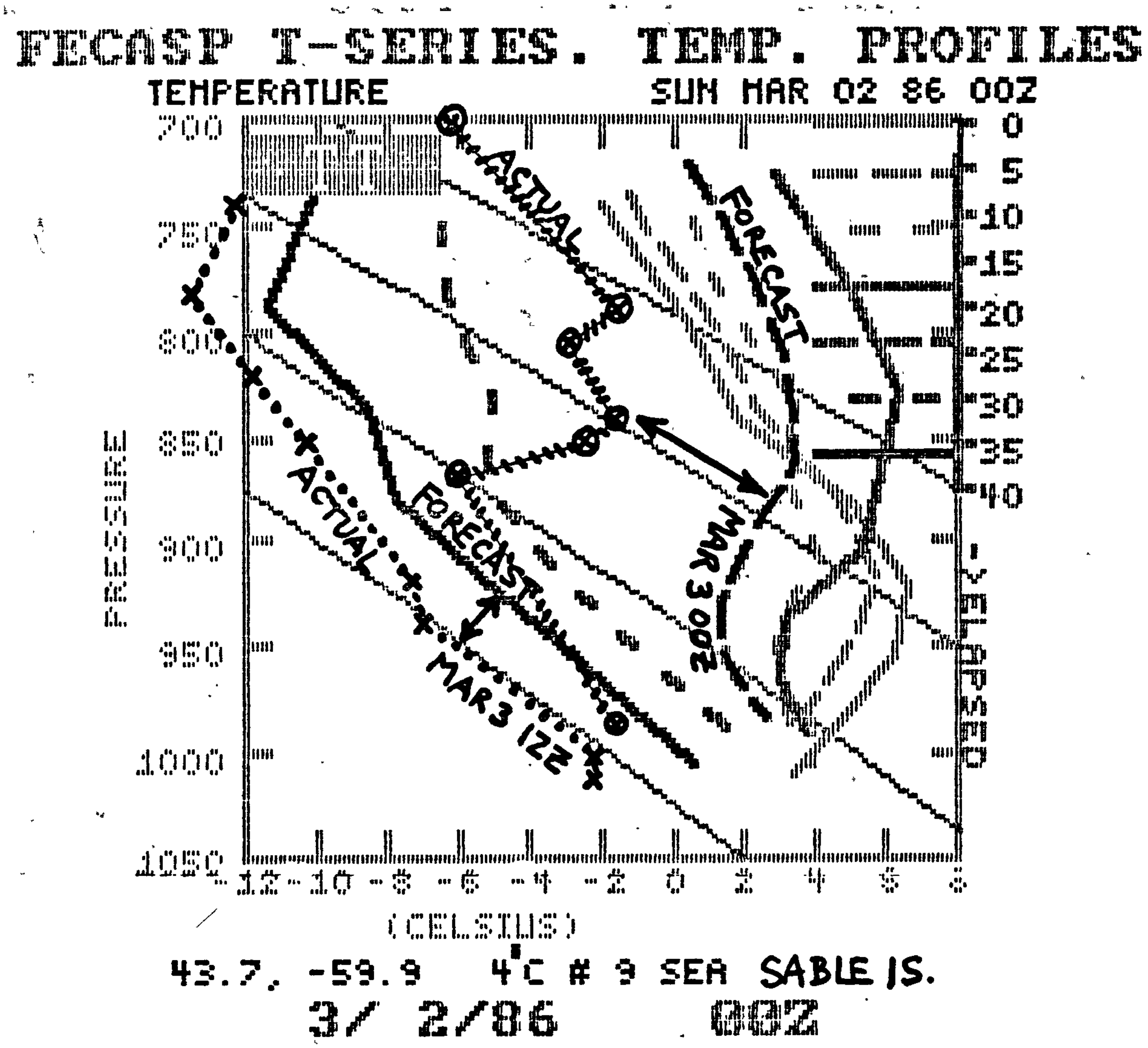

FECASP T-SERIES. TEMP. PROFILES
TEMPERATURE FRI JAN 24 88 00Z
ENVIRONMENT CANADA
PRESSURE
700
750
800
850
900
950
1000
1050
-14 -12 -10 -8 -6 -4 -2 0 2
(CELSIUS)
0
5
10
15
20
25
30
35
40
-ELAPSED
FORECAST
ACTUAL
JAN 25 12Z
JAN25 12Z (36HR)
43.7. -59.9 2°C + 9 SEA SABLE IS.
1/24/86 00Z

FIGURE 6A



ENVIRONNEMENT CANADA

FIGURE 6B

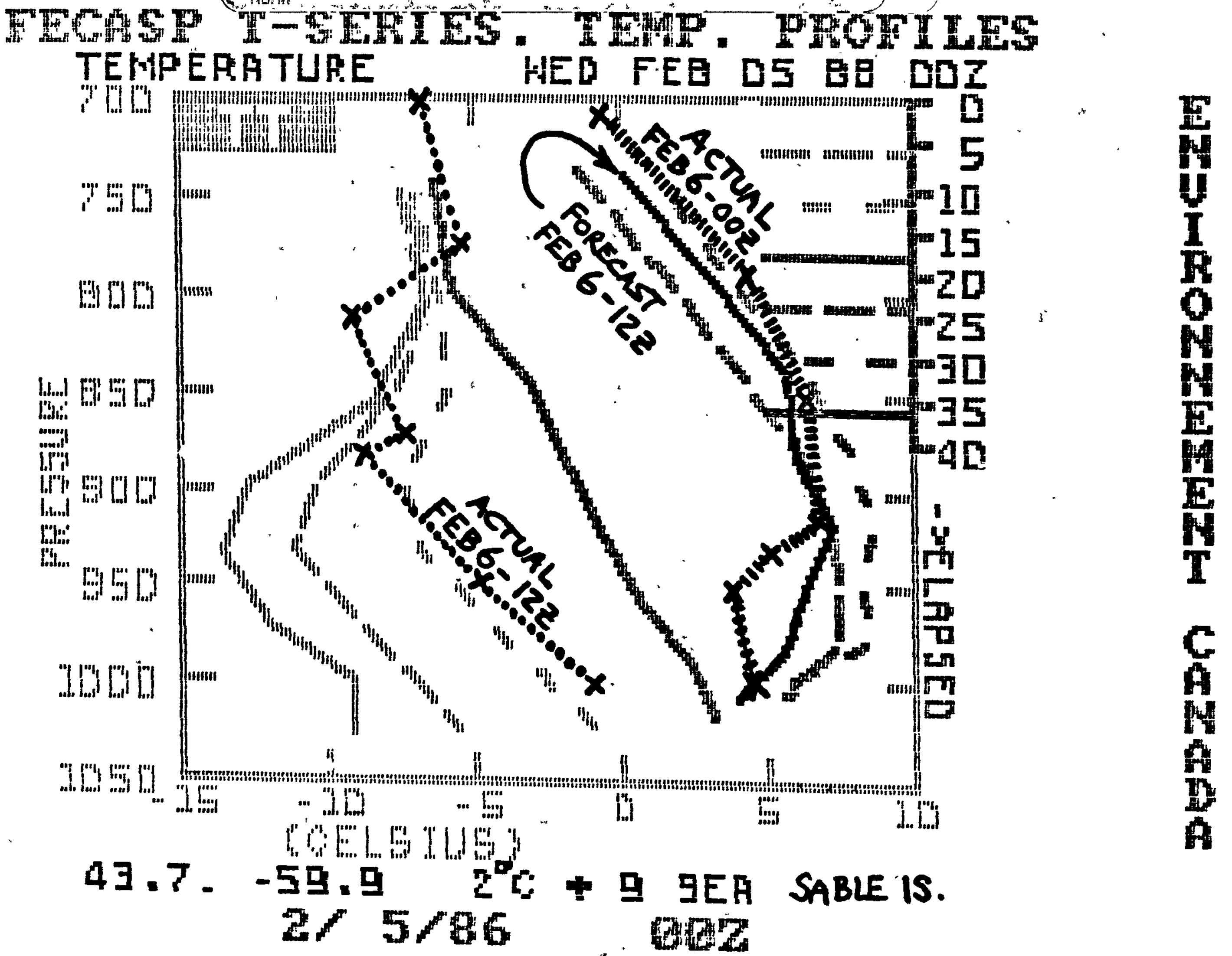

FECASP T-SERIES. TEMP. PROFILES
TEMPERATURE
WED FEB 05 88 00Z
700
750
800
850
900
950
1000
1050
PRESSURE
-15
-10
-5
0
5
10
(CELSIUS)
0
5
10
15
20
25
30
35
40
-ELAPSED
ACTUAL FEB 6-00Z
FORECAST FEB 6-12Z
ACTUAL FEB 6-12Z
43.7. -59.9 2°C + 9 9EA SABLE IS.
2/ 5/86 00Z
ENVIRONNEMENT CANADA

FIGURE 6C