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NATIONAL WEATHER SERVICE
NATIONAL METEOROLOGICAL CENTER

OFFICE NOTE 300

INTERCOMPARISON OF ECMWF AND NMC 500 MB HEIGHT FORECASTS TO 5 DAYS: 1984 UPDATE

Charles L. Vlcek

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This note is an update of Intercomparison of ECMWF and NMC 500 Mb Height Forecasts to 5 days by Bonner, Stackpole, and Vlcek (NMC Office Note 281, December 1983). The purpose of this update is to enlarge the data base for the intercomparison and to monitor the impact, if any, of the conversion of the ECMWF model from grid to spectral form in April 1983.

The original intercomparison used verification of forecasts against radiosonde data in three areas: the entire northern hemisphere (NH102), North America (NA110), and Europe (EUR96) -- the numbers refer to the number of stations representing each area. The same three areas were used in the update. In a nutshell, the European area showed no significant change in the relative performance of the NMC & ECMWF models after the conversion while the ECMWF model improved with respect to the NMC model in the North American and Northern Hemisphere areas.

Before we look at the data it should be mentioned that the statistics for May 1983 are not available due to technical problems. Also, the types of figures used in the original paper are used again here but the order of presentation is somewhat different.

The "mean time advantage" graphs (Fig. 1a, b, c) are presented first here because the "nutshell" results described earlier really leap out. Mean time advantage is the additional forecast time it takes for model B to reach the same error value as model A, assuming that the errors of both models increase more or less linearly with time. The "error" referred to here is the standard "error" (or standard deviation) of the 500 mb height forecast. The "mean" time advantage (represented by circles) is the average of 12 consecutive individual monthly time advantage values. It should be noted that the second year of data runs from June 1983 through May 1984 because of the unavailability of the May 1983 data.

As in the original Office Note, the time advantage is given with respect to the ECMWF model at the time of the ECMWF forecast. Thus a 5 hour advantage at 24 hours means that the NMC model required an average of only 19 hours to reach the error level that the ECMWF model reached at 24 hours. Incidentally, the example given in Office Note 281 (first paragraph of mean time advantage discussion) contains an error. The bottom line "asserts that the ECMWF

model is 10 hours 'better'", whereas it should have stated that NMC was 10 hours 'better' in that example.

It should also be noted that in computing the time advantage, the NMC forecast errors were interpolated from 12 hour intervals for the first year data and from 24 hour intervals for the second year. The effect of the difference in computation is slight since the error increases nearly linearly with time.

The ECMWF model clearly increased its advantage over NMC in the Northern Hemisphere and North American areas during the second year. The question is, did the ECMWF model get better or was the NMC model worse? Were two or three "abnormal" months responsible for the results?

Figure 2 (a,b,c), when compared with Figure 6 (a,b,c) from Office Note 281, provides some answers to these questions by showing the actual mean standard error versus forecast hour for each model. The European area shows little change in the error values of either model between the first and second years. In the other two areas the European model improved slightly and the the NMC model was slightly worse in the second year. The magnitude of the change ranged from one to four meters for both models. The main exception is the 120 hour forecast in the North American area where the ECMWF model showed no change while the NMC model increased its error by 6 meters. A tabulation of these changes are given in table 1.

The contribution of individual monthly error values to the overall results is shown by the time-series graphs in Figure 3 (a,b,c). Here the entire period from April 1982 to July 1984 is shown, and the absence of May 1983 data actually makes it easier to assess the "before" and "after" comparisons at a glance. The increased separation between the ECMWF and model error curves seems to be more or less uniform for the NH102 and NA110 areas although there is a slightly more amplified winter maximum in the second year. In Europe the winter maxima of the indiviual errors amplify somewhat in both models during the second year; otherwise there is little change.

The annual mean 500 mb height error statistics for June 1983 through May 1984 are shown in Figure 4 (a,b,c). These graphs basically show little difference from the previous year (Figure 2 (a,b,c) in Office Note 281). The major exception is that the NMC model much more closely parallels the ECMWF model in the European area during the second year than during the first year.

Figures 5 (a,b,c), 6 (a,b,c) and 7 (a,b,c) show month to month variations in mean error for the three areas and for 24, 72, and 120 hour forecasts. Again the missing May 1983 data simplifies the "before" and "after" comparisons. The NMC model show even greater seasonal variation

in the second year than in the first (areas NH102 and NA110) while the ECMWF model has the same or slightly less variation in the second year. The other major difference is that the NMC model becomes more closely aligned with the ECMWF model in the second year at 72 hours (EUR96); this difference also showed up in the comparison of mean annual error discussed in the previous paragraph.

Overall the data presented little change, from the first year to the second, in the general characteristics of the two models with respect to mean error (all areas) or standard error in EUR96. With respect to standard error, the ECMWF model showed some improvement in NH102 and NA110 and the NMC model grew slightly worse in those two areas. The mean time advantage comparisons tend to magnify these changes because of the rather shallow slope of the standard error vs forecast hour function. A more extreme example of this sort of thing is shown in Figure 8 where the spectral model (NMC) has its greatest time advantage--and smallest error advantage--over persistence at 192 hours. All systems should ultimately attain zero skill, but skill is not what is being measured here. The standard error for 500 mb height forecast is a quantity that not only has a finite upper limit but also favors the smoothest model in low-skill situations. The smooth model will level off with forecast time at a slightly lower error value than the rough model and so ultimately attain an infinite time advantage over the rough model. Not to worry--both models will probably be worse than climatology by that time. The point is the following caveat: time advantage scores can be misleading at times.

Even with this caveat firmly in mind, a person can plainly see that the ECMWF model did improve somewhat with respect to the NMC model during the second year. That leaves two questions to be answered. First, is the improved ECMWF model performance at a significant level? Second, if the improvement is significant, is it due to changes in the ECMWF model?

The answer to these questions are revealed in Table 1, another nutshell-at-a-glance presentation. The rows labelled 'NMC' represents the change (in meters) in the average standard 500 mb height error, from the first year to the second, of 24, 48, 72, 96, and 120 hour NMC forecasts for the three areas (NH102, NA110, EUR96). The corresponding change in standard error values for ECMWF forecasts are tabulated in the rows labelled 'ECMWF'.

The rows labelled 'T-SCORES' represent the Student's t test for the significance level of the year to year change of the 500 mb height error difference between NMC and ECMWF forecasts. The t-scores could be considered a tabular representation of Fig. 1, with standard error differences substituted for time advantage. The t-scores also represent what is seen in Fig. 3 (which show only 24, 72, and 120 hour forecast errors) in terms of year to year change in the spacing between NMC-ECMWF pairs of curves.

The t-scores are all positive, indicating that in each case the

ECMWF model performed better, with respect to the NMC model, in the second year than in the first. However, the only significant values are for 24 and 48 hours in areas NH102 and NA110, all of which are significant at the 1% level. In fact the t-scores would have remained significant even if there had been no change in the annual NMC standard error values. The 48 hour t-score in NA110 would have had a value of 2.47 which would have been significant only at the 5% level, but the other three significant values would have remained above 2.82 which defines the 1% level.

These results suggest that the conversion of the ECMWF model to a spectral format did have a significant positive impact on short range forcasts over wide areas. The EUR96 area is so compact that the result there may not be entirely representative. More weight should be given to large areas such as NH102.

The impact on longer range forcasts is harder to assess. The lack of significantly large values of t is at least partly due to the larger month to month variation in the standard error differences so that a very large change in the mean standard error difference (10-15 meters) is required to be considered significant even at the 5% level. The actual change in in the mean standard error difference between NMC and ECMWF seems to hold nearly steady or increase slightly with forecast time. This pattern suggests that the effect of the conversion of the ECMWF model to spectral form is focused on the short range forecasts--possibly even the analysis--and is simply carried over into the longer range forecasts where the significance of the impact gets swallowed up in noise.

Although the change in the ECMWF model is considered to be the primary cause of the apparent improvement in its performance, another possibility is worthy of mention. The weather pattern itself may have changed during the second year to a type better handled by the ECMWF model. This suggestion is more easily understood if one considers the impact of an increasingly barotropic regime on the relative performance of barotropic and baroclinic models.

An interesting sidelight is the downward trend of the standard error change values, from day 1 to day 5, in both models as shown in Table 1. Another glance at Fig. 3 shows greater amplitude in the seasonal maximum in the winter of 1983-84 than during the previous winter. Since the amplitude of the seasonal maximum increases with forecast time, the overall effects of the year to year change is most pronounced at 120 hours. The cause of the higher standard error in the winter of 1983-84 may be a more active weather regime (decreased persistence) since seasonal changes in forecast performance seem to follow changes in persistence to a fair degree. Unfortunately this bit of conjecture cannot be fully tested since verifications of longer range persistence forecasts did not begin until December 1983.

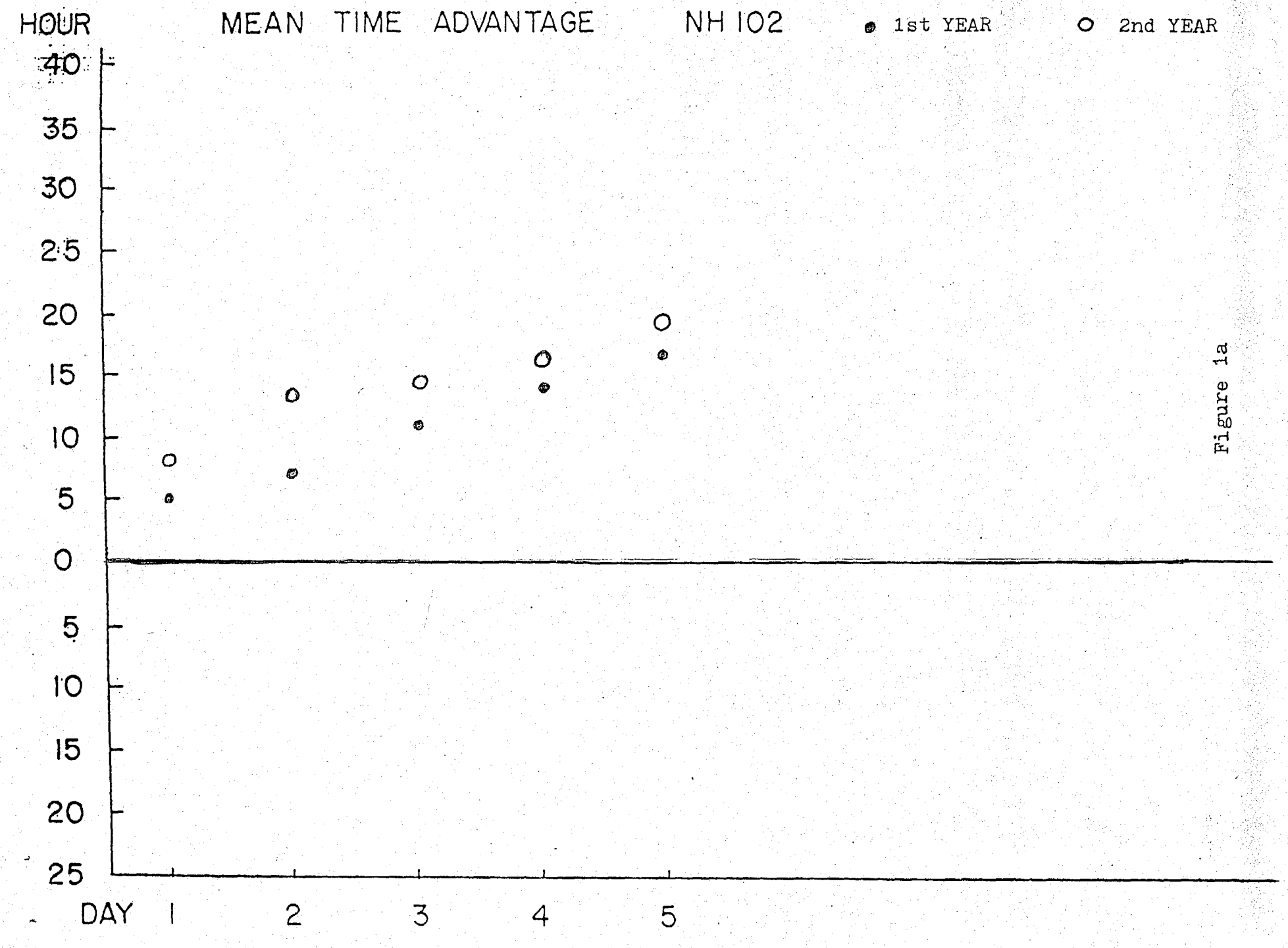

HOUR
MEAN TIME ADVANTAGE
NH 102
1st YEAR
2nd YEAR
40
35
30
25
20
15
10
5
0
5
10
15
20
25
DAY
1
2
3
4
5

Figure 1a

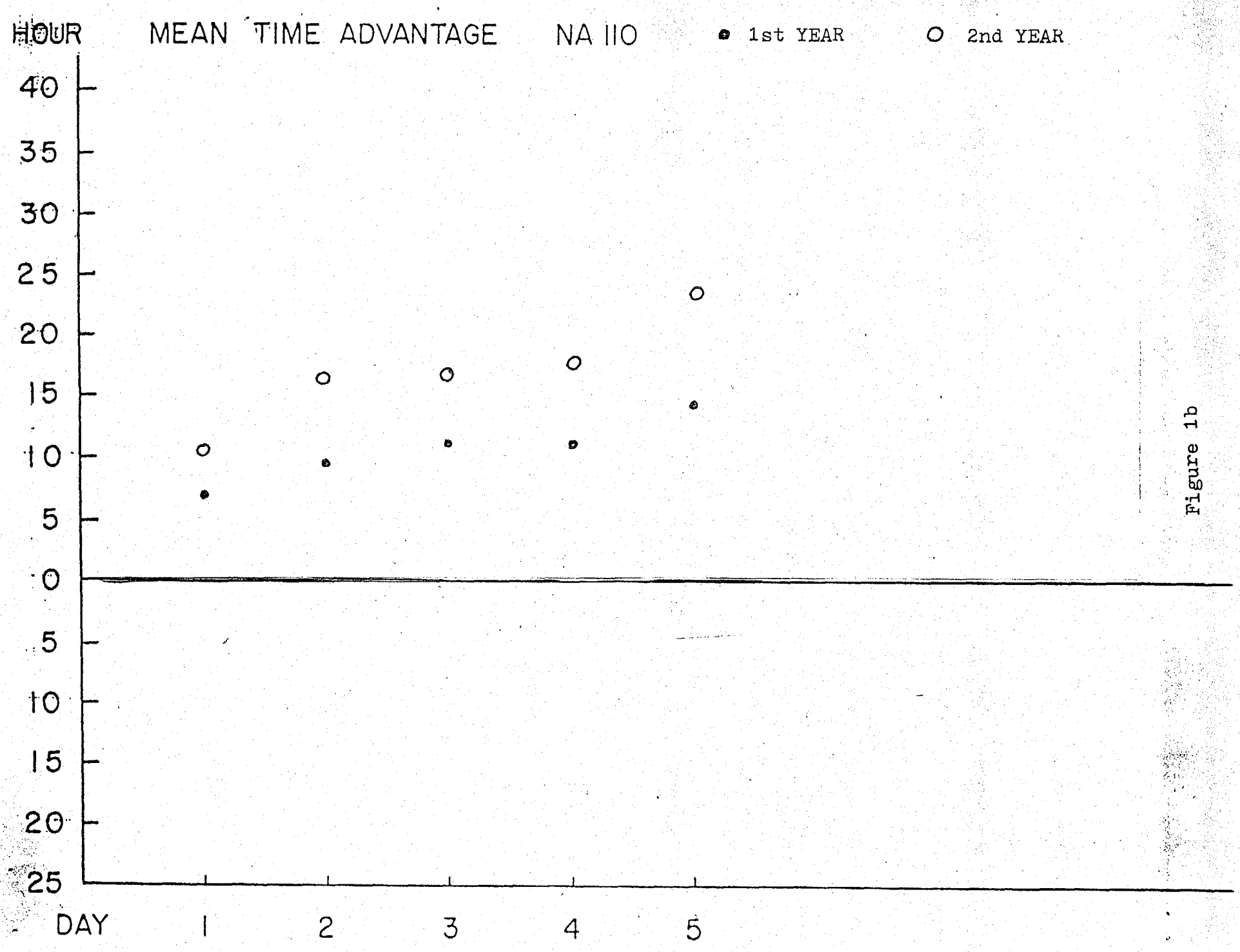
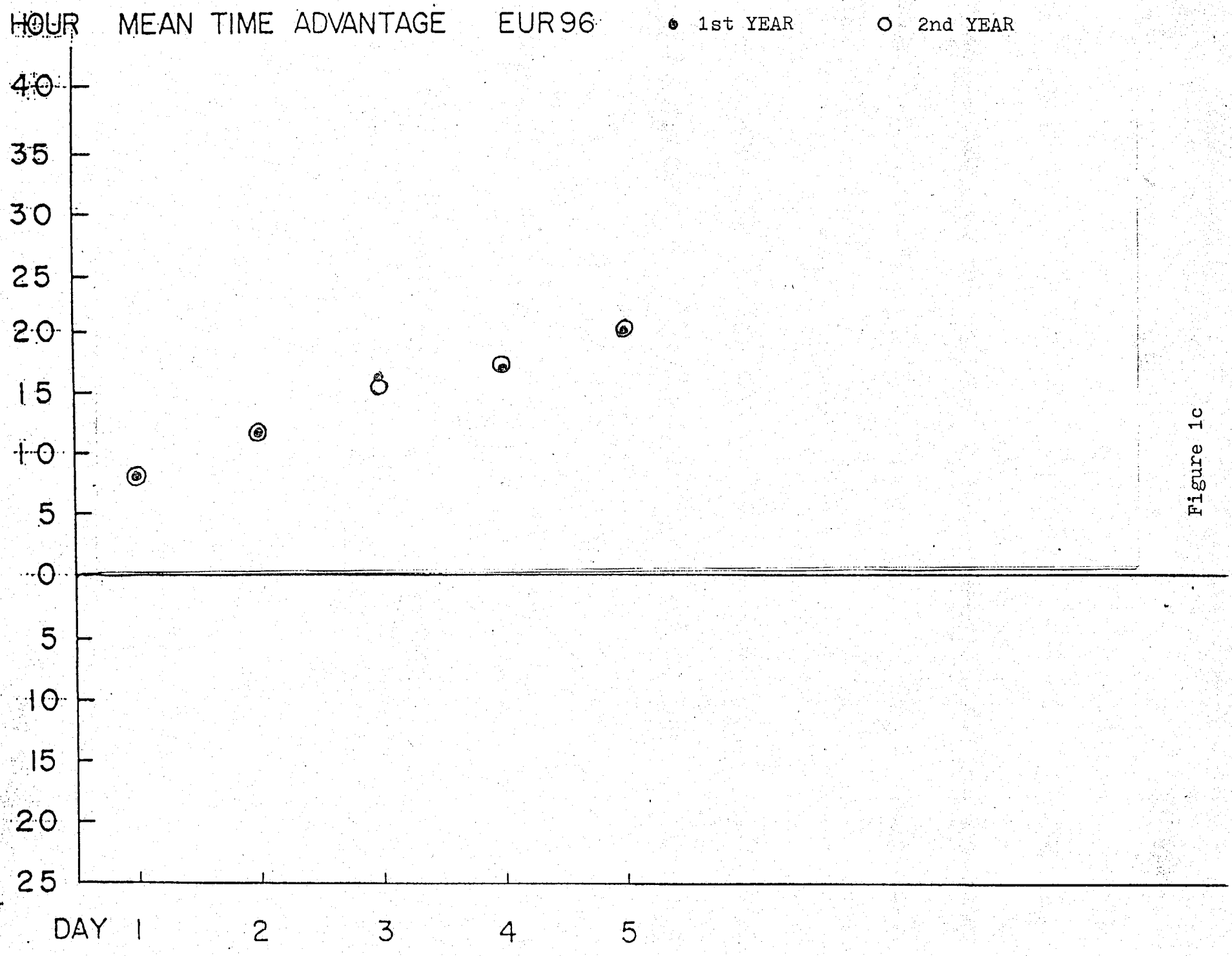

HOUR
MEAN TIME ADVANTAGE
NA 110
1st YEAR
2nd YEAR
40
35
30
25
20
15
10
5
0
5
10
15
20
25
DAY
1
2
3
4
5

Figure 1b


HOUR
MEAN TIME ADVANTAGE
EUR 96
1st YEAR
2nd YEAR
40
35
30
25
20
15
10
5
0
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10
15
20
25
DAY
1
2
3
4
5

Figure 1c

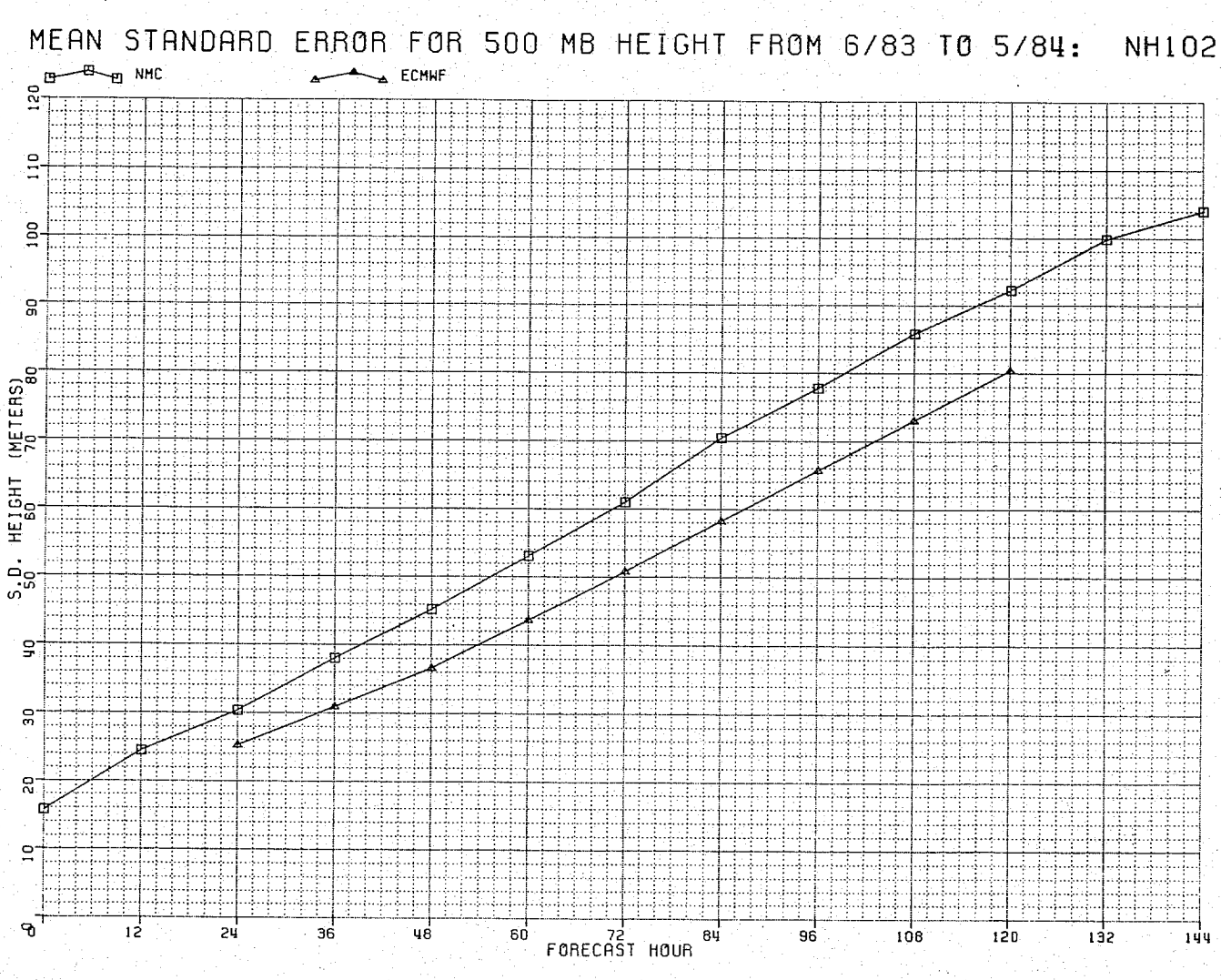

MEAN STANDARD ERROR FOR 500 MB HEIGHT FROM 6/83 TO 5/84: NH102
NMC
ECMWF
S.D. HEIGHT (METERS)
0
10
20
30
40
50
60
70
80
90
100
110
120
12
24
36
48
60
72
84
96
108
120
132
144
FORECAST HOUR

Figure 2a

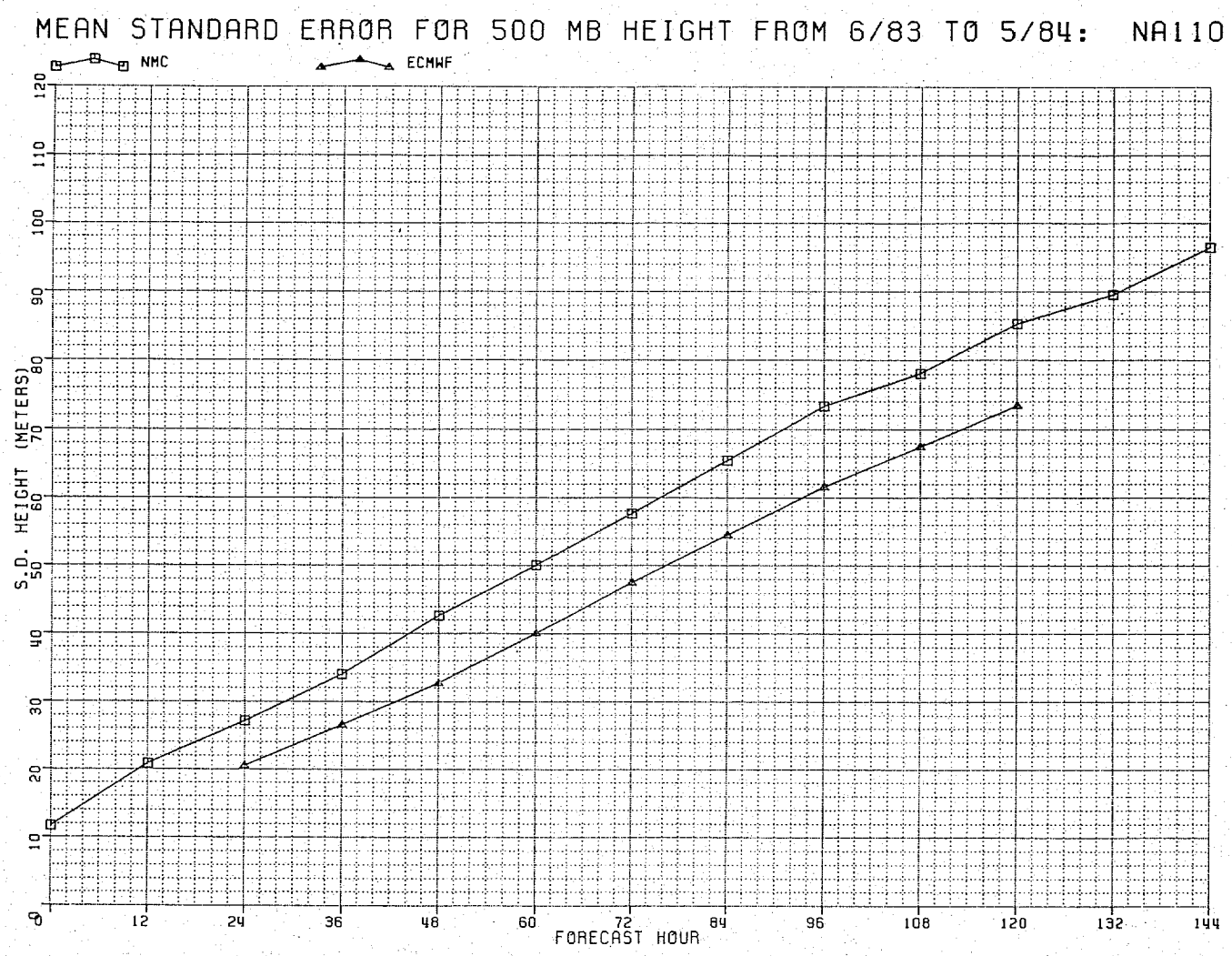

MEAN STANDARD ERRØR FØR 500 MB HEIGHT FRØM 6/83 TØ 5/84: NA110
NMC
ECMWF
S.D. HEIGHT (METERS)
0
10
20
30
40
50
60
70
80
90
100
110
120
0
12
24
36
48
60
72
84
96
108
120
132
144
FORECAST HOUR

Figure 2b

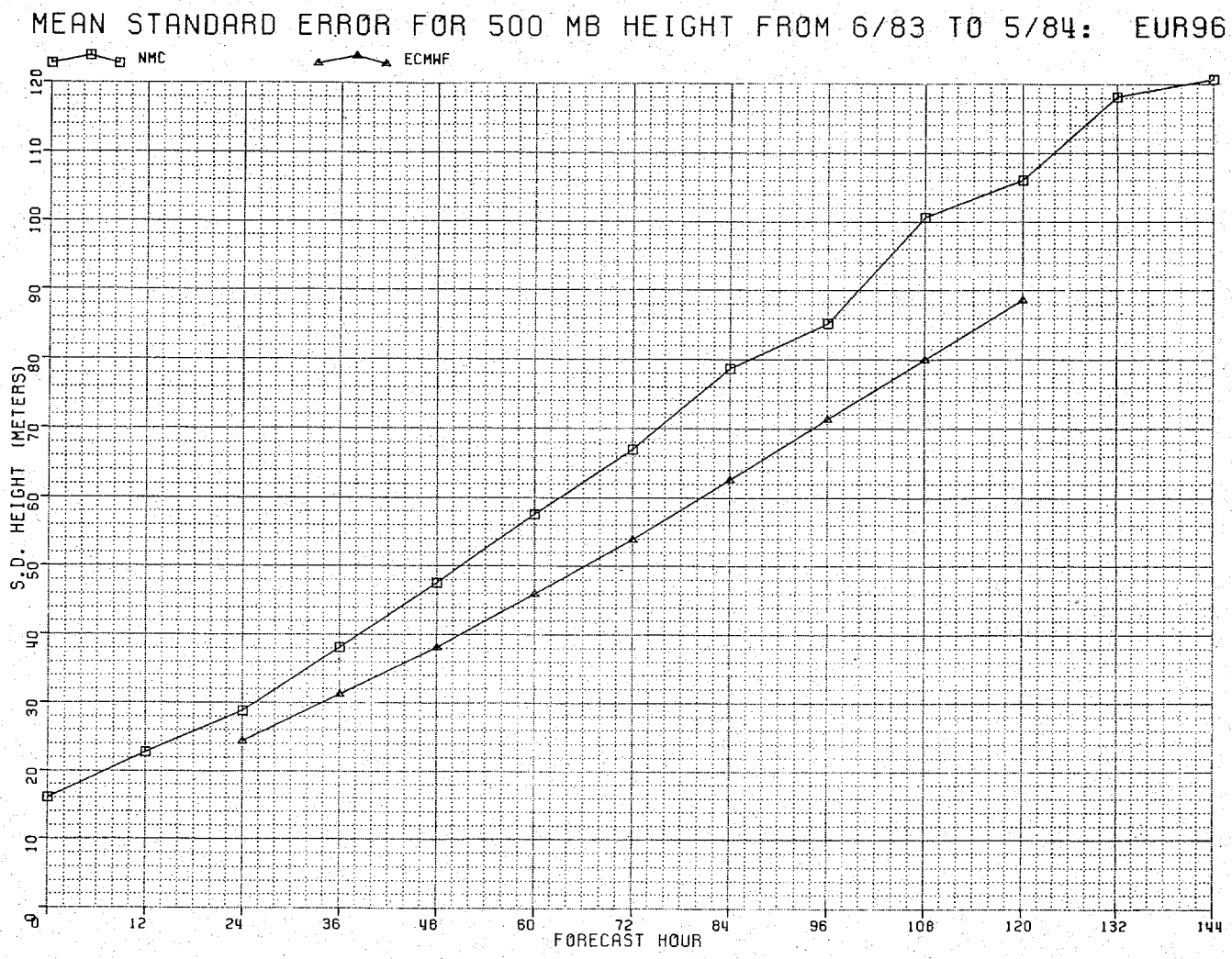

MEAN STANDARD ERROR FOR 500 MB HEIGHT FROM 6/83 TO 5/84: EUR96
NMC
ECMWF
S.D. HEIGHT (METERS)
0
10
20
30
40
50
60
70
80
90
100
110
120
0
12
24
36
48
60
72
84
96
108
120
132
144
FORECAST HOUR

Figure 2c

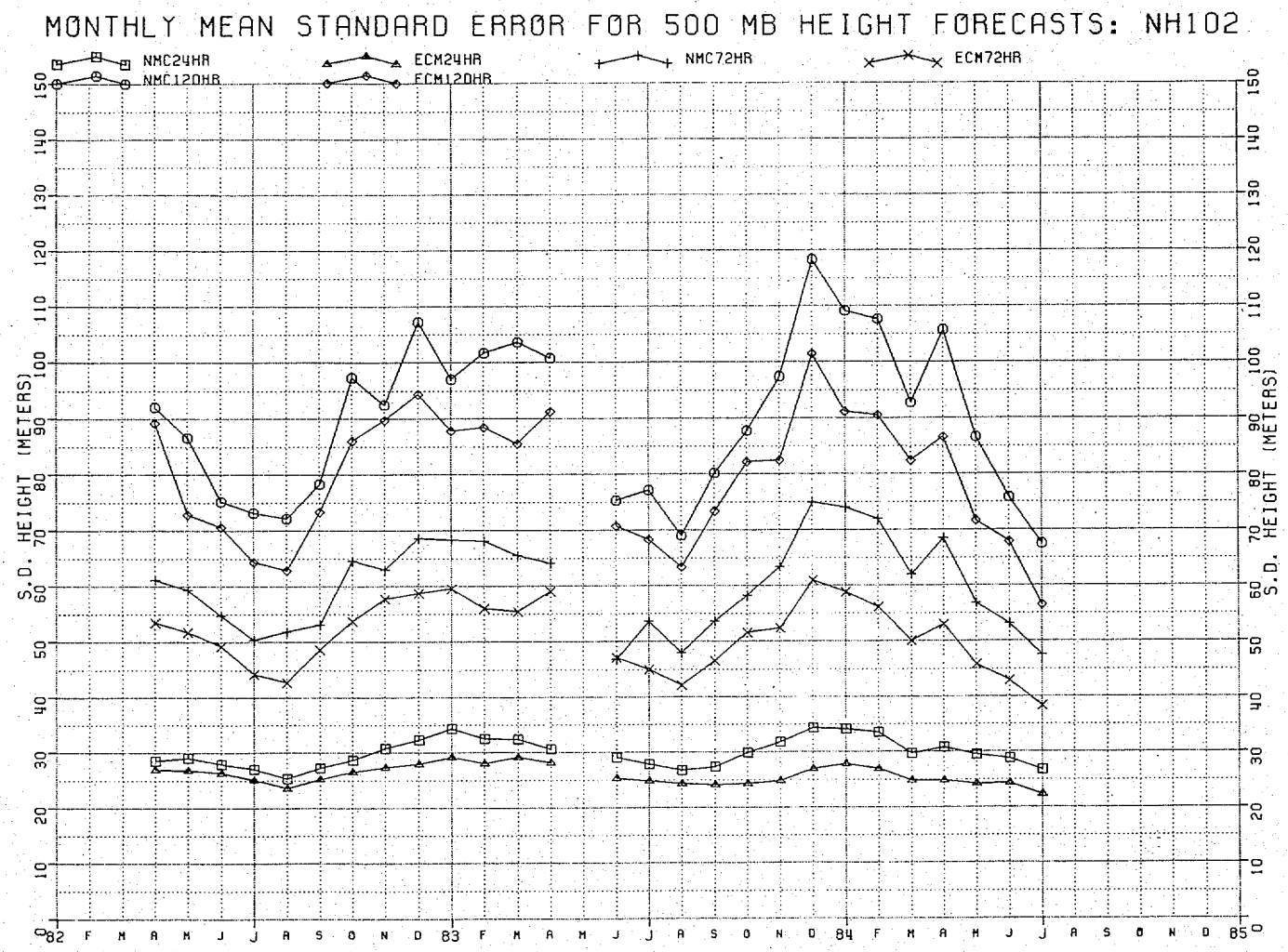

MONTHLY MEAN STANDARD ERROR FOR 500 MB HEIGHT FORECASTS: NH102
NMC24HR
NMC120HR
ECM24HR
ECM120HR
NMC72HR
ECM72HR
S.D. HEIGHT (METERS)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
82 F M A M J J A S O N D 83 F M A M J J A S O N D 84 F M A M J J A S O N D 85

Figure 3a

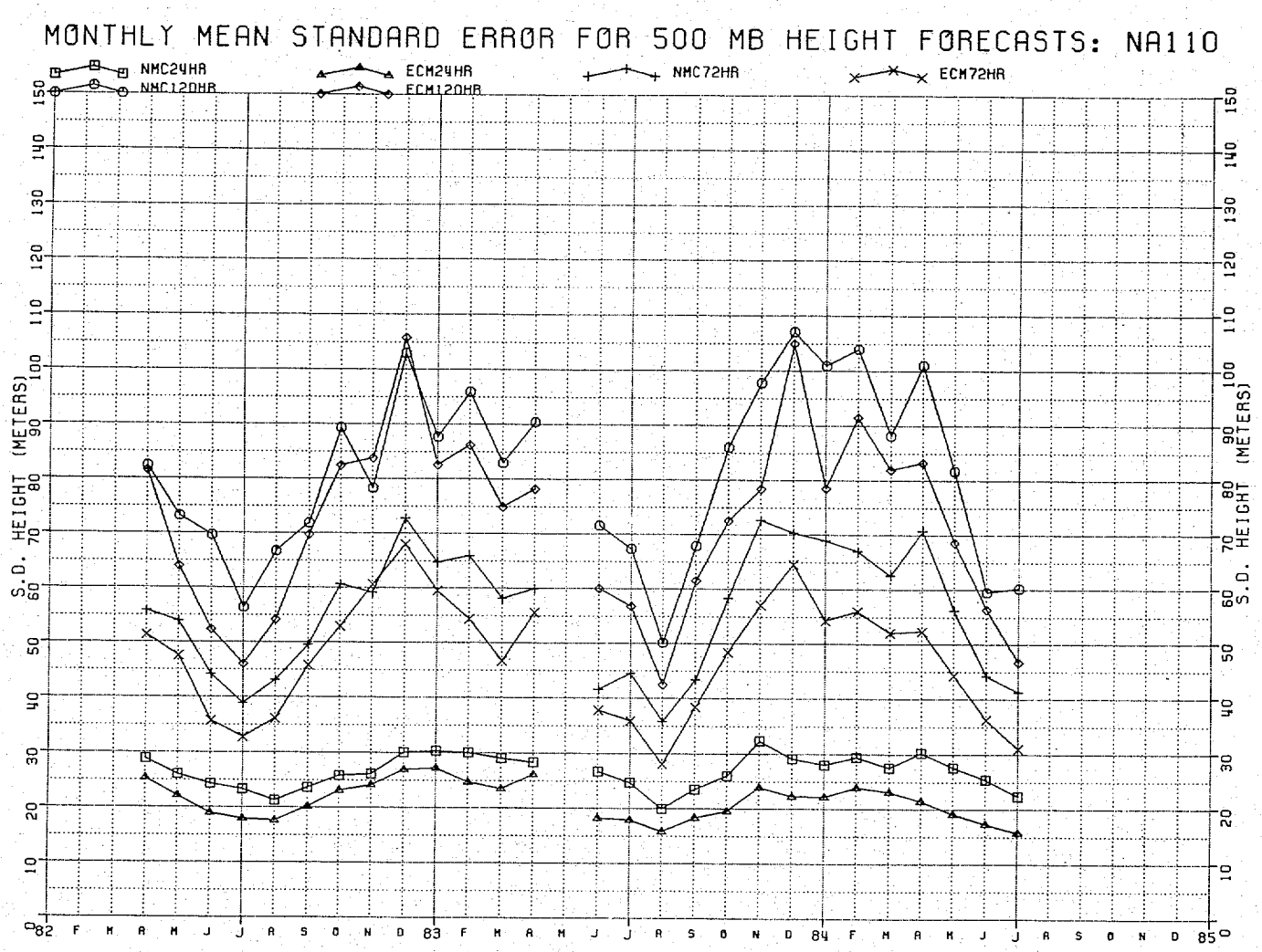

MONTHLY MEAN STANDARD ERROR FOR 500 MB HEIGHT FORECASTS: NA110
NMC24HR
NMC120HR
ECM24HR
ECM120HR
NMC72HR
ECM72HR
S.D. HEIGHT (METERS)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
82 F M A M J J A S O N D 83 F M A M J J A S O N D 84 F M A M J J A S O N D 85

Figure 3b

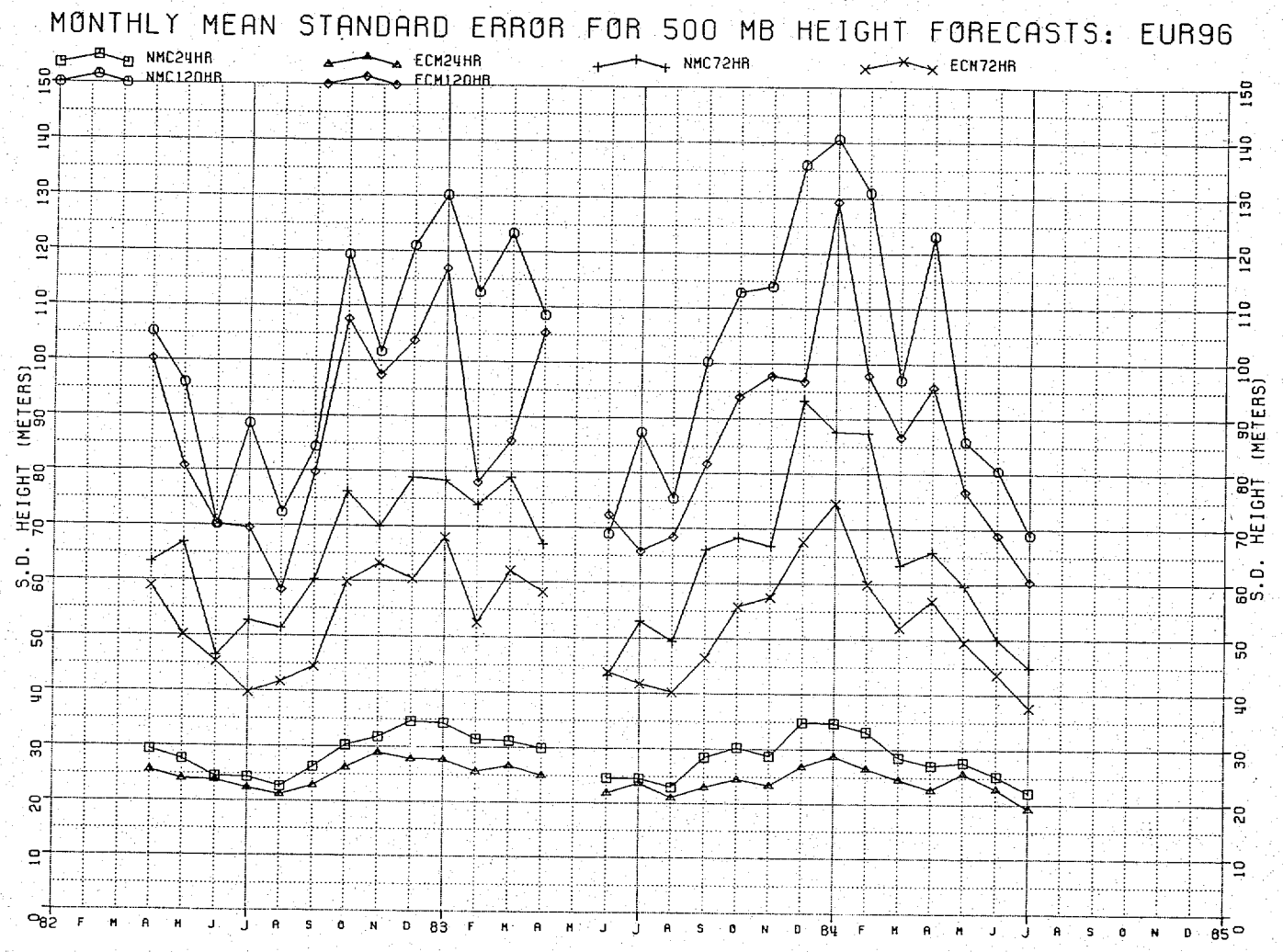

MONTHLY MEAN STANDARD ERROR FOR 500 MB HEIGHT FORECASTS: EUR96
NMC24HR
NMC120HR
ECM24HR
ECM120HR
NMC72HR
ECM72HR
S.D. HEIGHT (METERS)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
82 F M A M J J A S O N D 83 F M A M J J A S O N D 84 F M A M J J A S O N D 85

Figure 3c

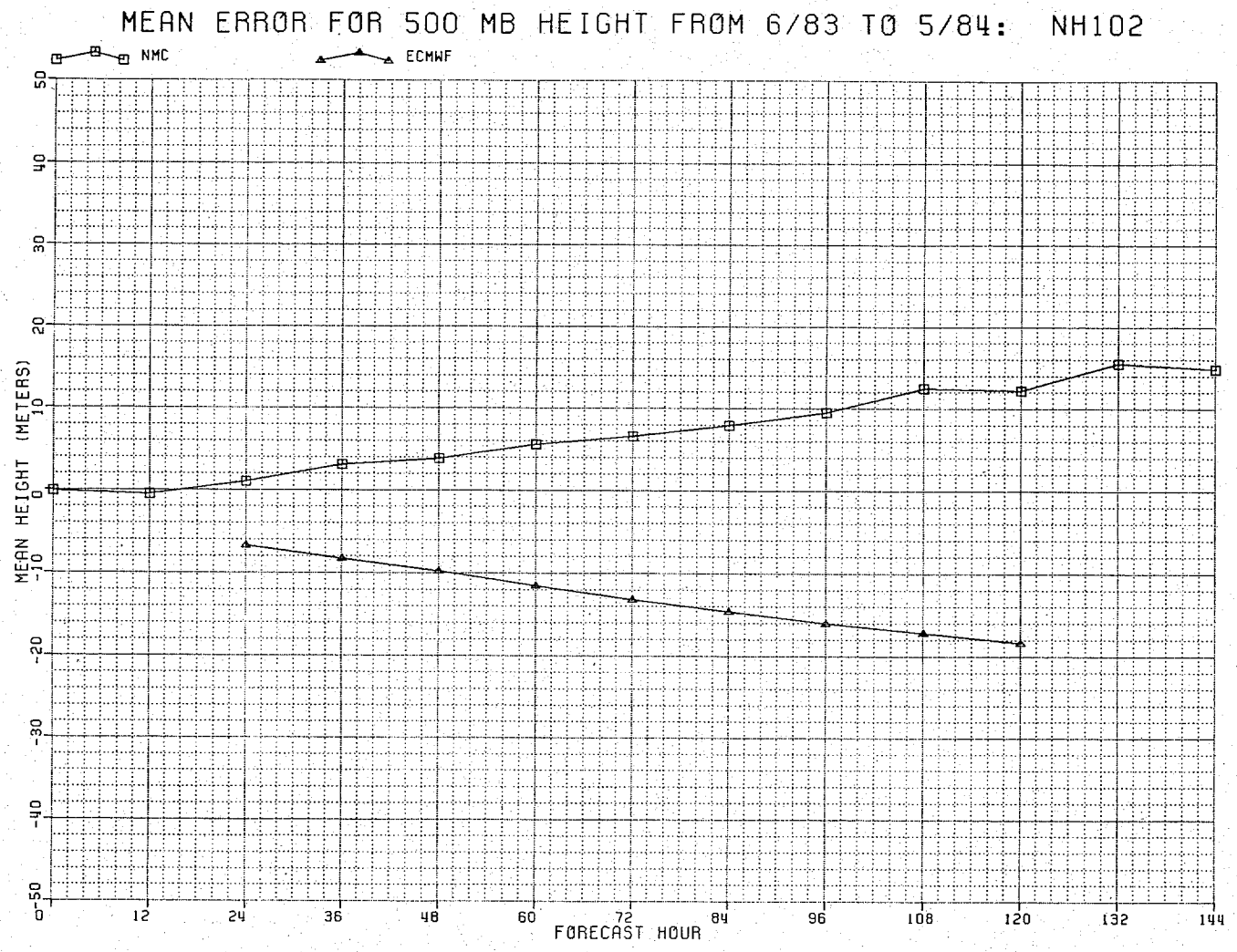
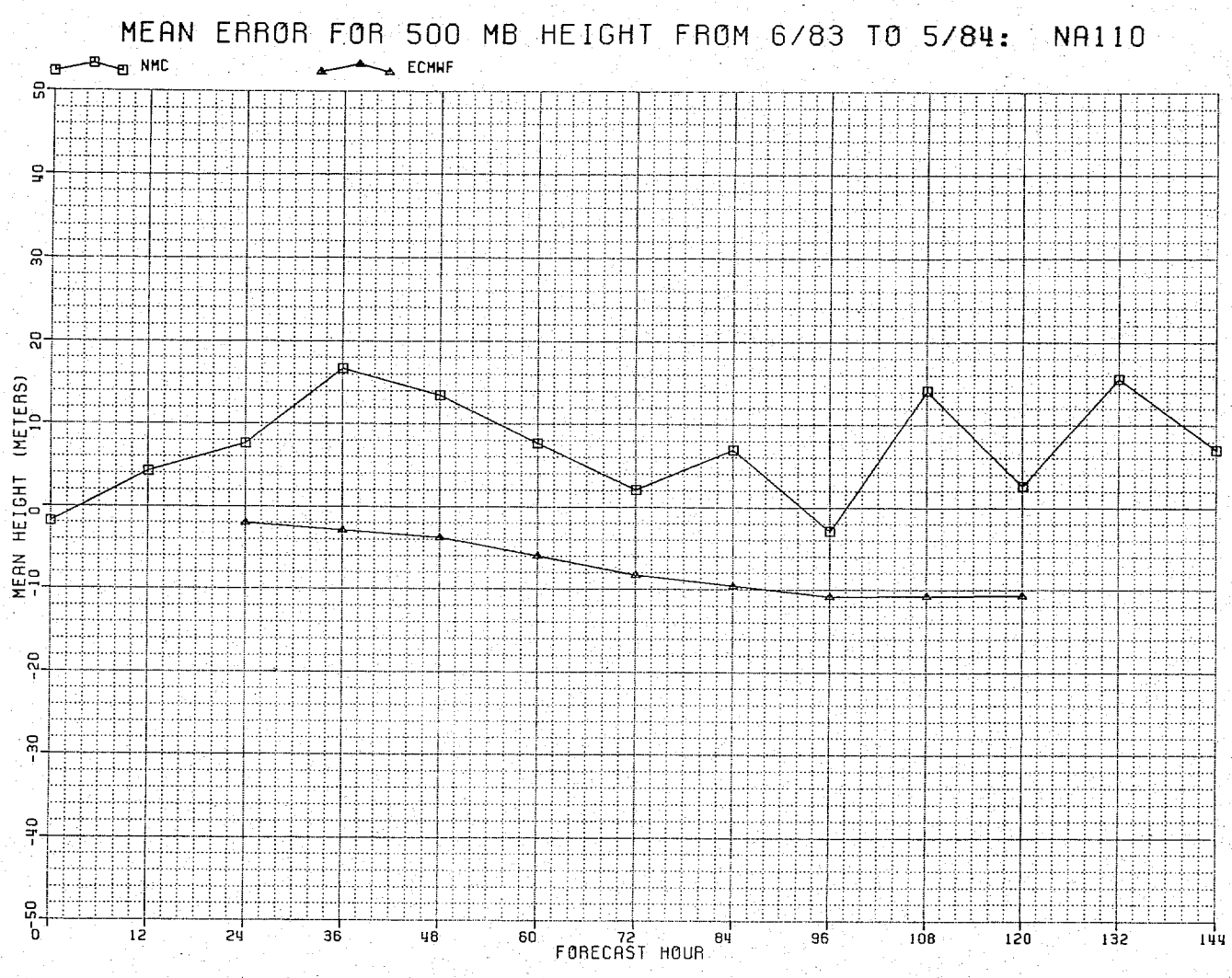

MEAN ERROR FOR 500 MB HEIGHT FROM 6/83 TO 5/84: NH102
NMC
ECMWF
MEAN HEIGHT (METERS)
50
40
30
20
10
0
-10
-20
-30
-40
-50
0
12
24
36
48
60
72
84
96
108
120
132
144
FORECAST HOUR

Figure 4a


MEAN ERROR FOR 500 MB HEIGHT FROM 6/83 TO 5/84: NA110
NMC
ECMWF
MEAN HEIGHT (METERS)
50
40
30
20
10
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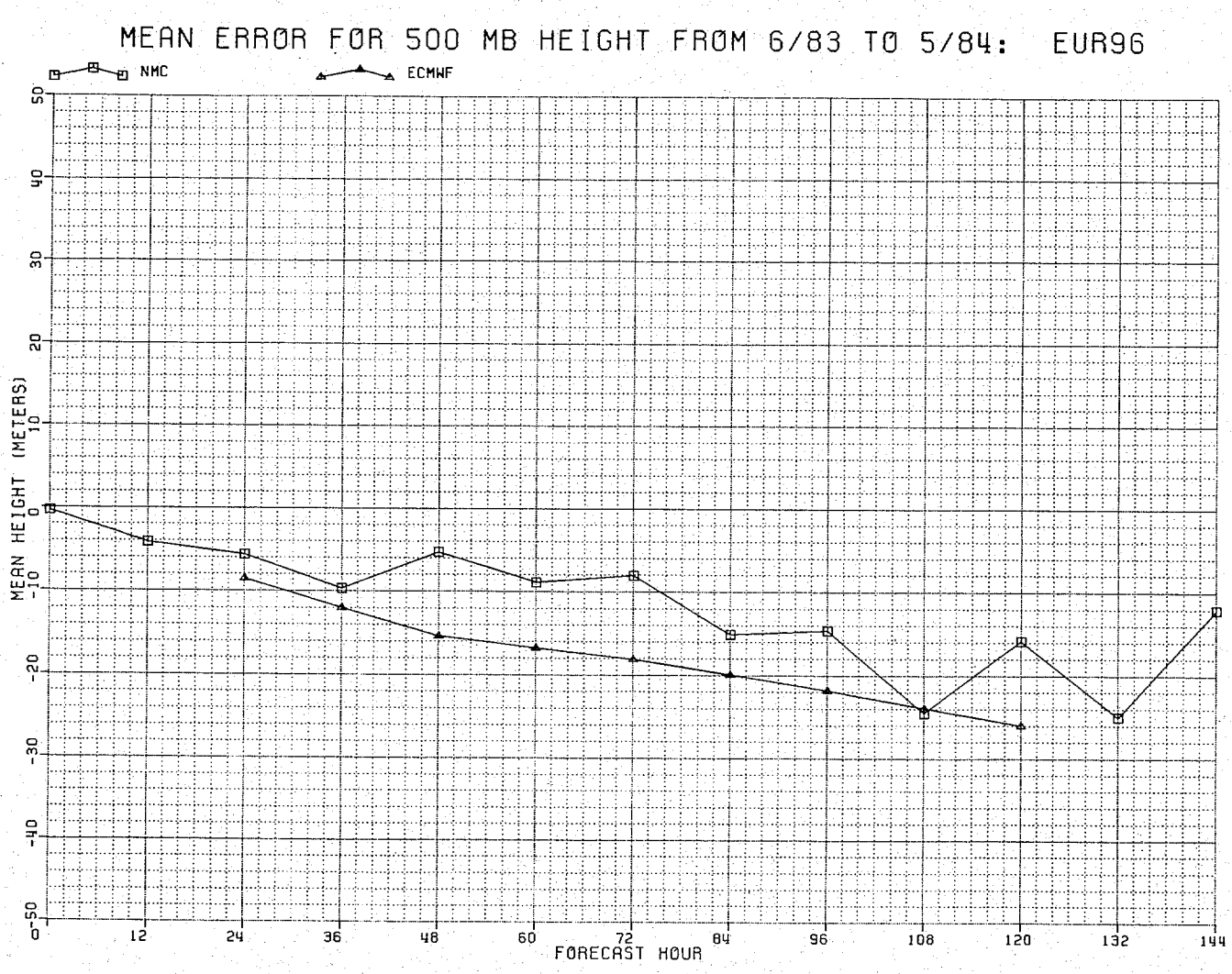
-10
-20
-30
-40
-50
0
12
24
36
48
60
72
84
96
108
120
132
144
FORECAST HOUR

Figure 4b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NMC
ECMWF
MEAN HEIGHT (METERS)
50
40
30
20
10
0
-10
-20
-30
-40
-50
0
12
24
36
48
60
72
84
96
108
120
132
144
FORECAST HOUR

Figure 4c

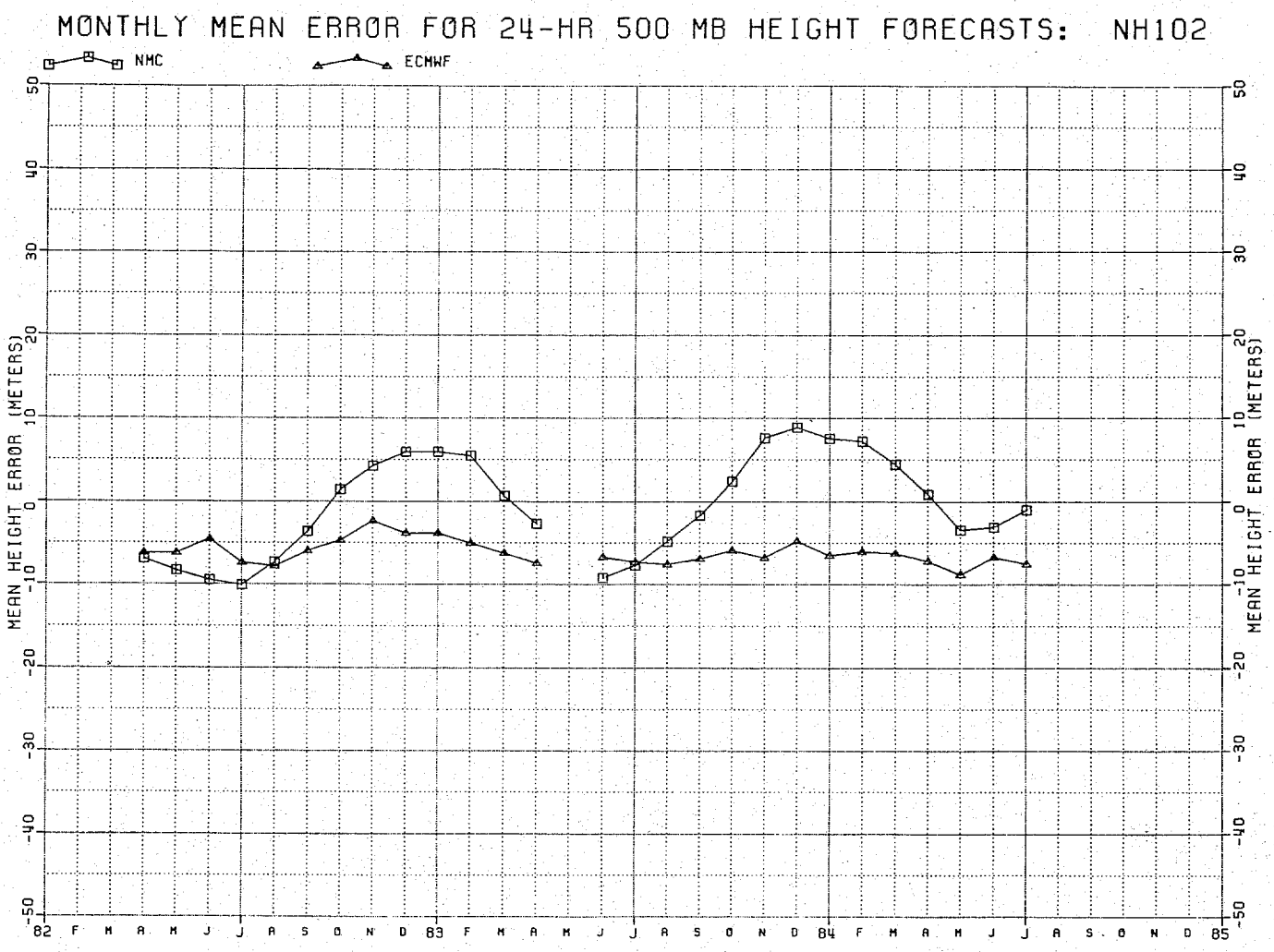
MONTHLY MEAN ERROR FOR 24-HR 500 MB HEIGHT FORECASTS: NH102
NMC
ECMWF
MEAN HEIGHT ERROR (METERS)
50
40
30
20
10
0
-10
-20
-30
-40
-50
82 F M A M J J A S O N D 83 F M A M J J A S O N D 84 F M A M J J A S O N D 85

Figure 5a

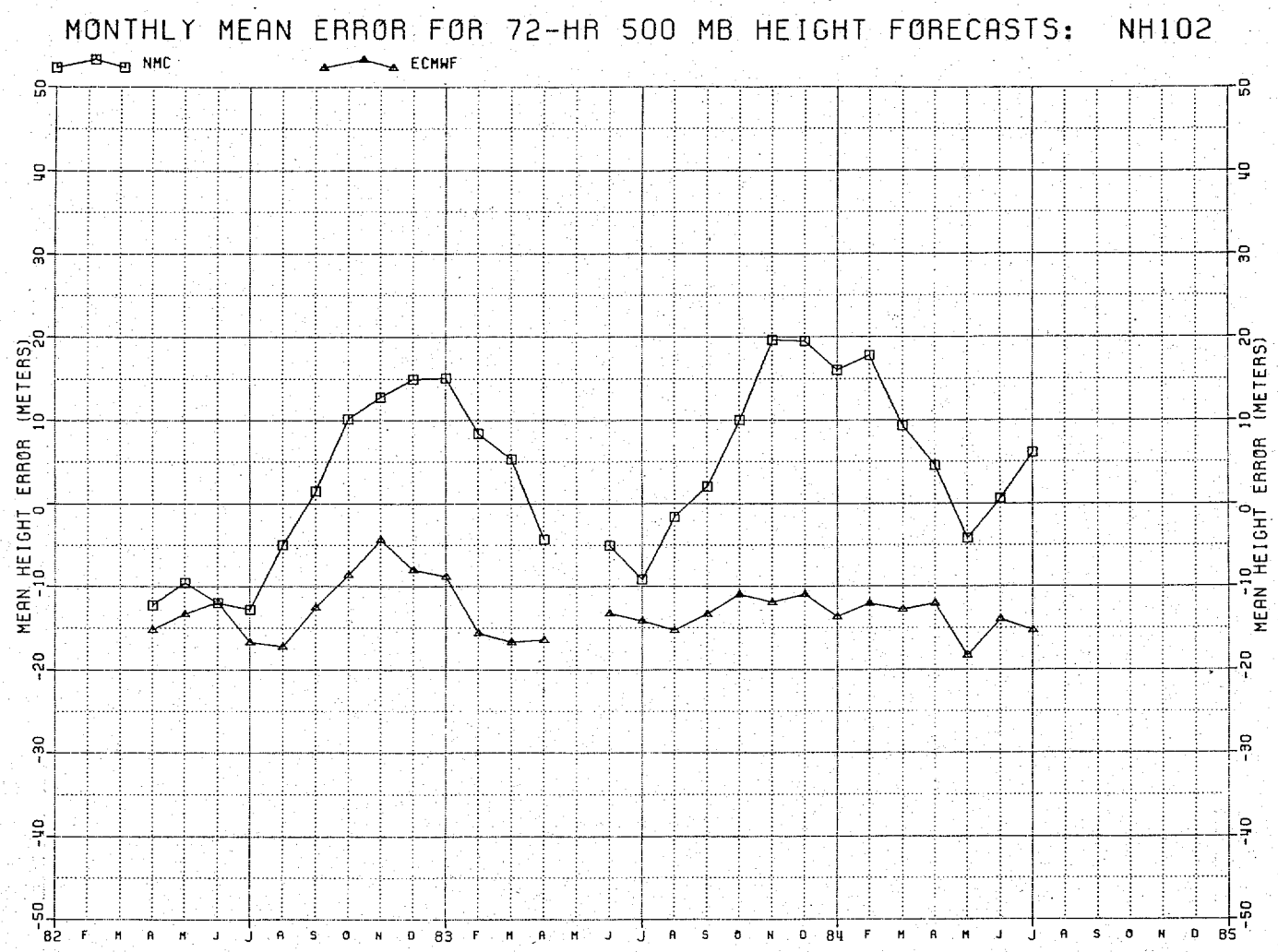
MONTHLY MEAN ERROR FOR 72-HR 500 MB HEIGHT FORECASTS: NH102
NMC
ECMWF
MEAN HEIGHT ERROR (METERS)
50
40
30
20
10
0
-10
-20
-30
-40
-50
82 F M A M J J A S O N D 83 F M A M J J A S O N D 84 F M A M J J A S O N D 85

Figure 5b

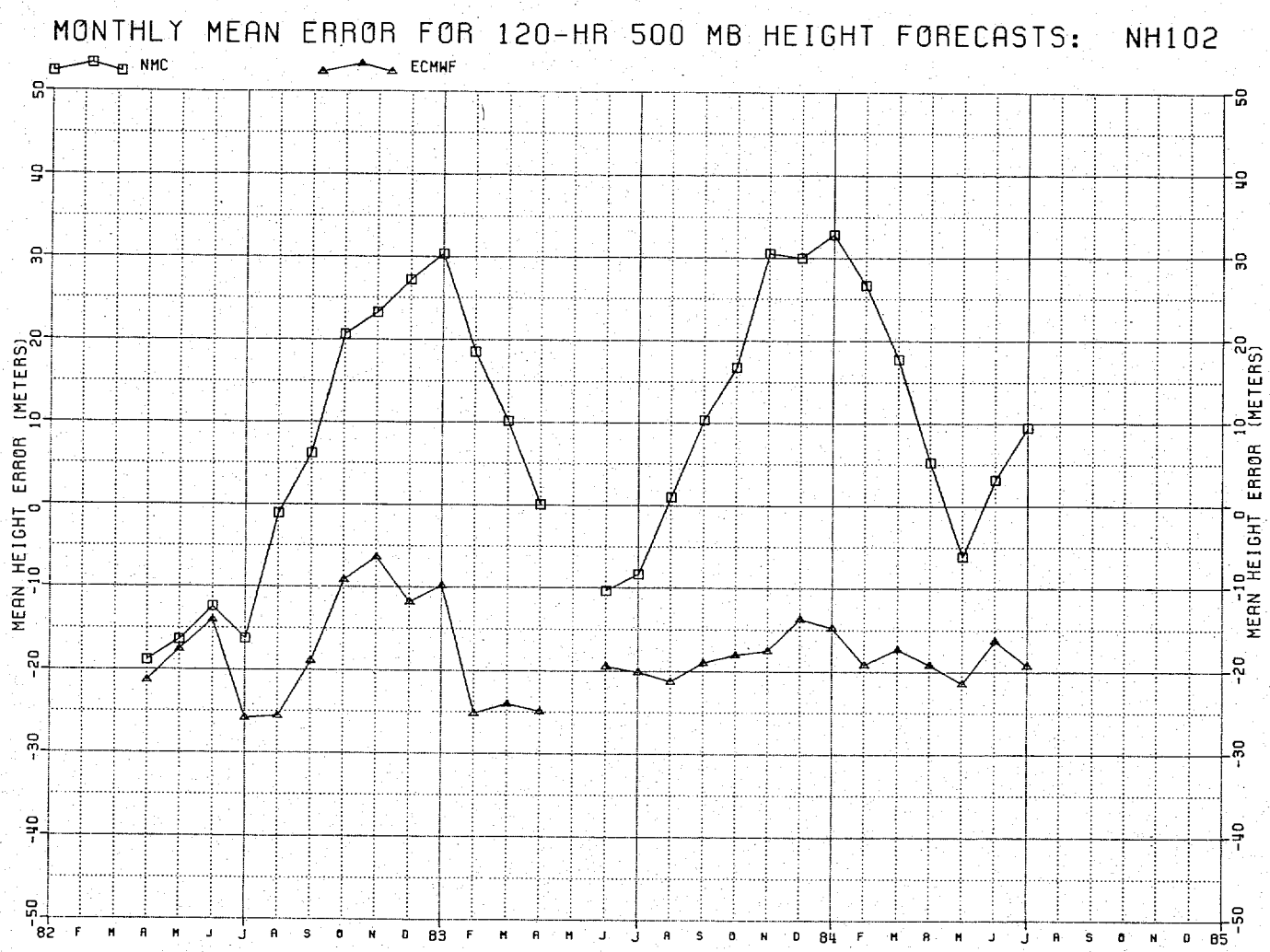
MONTHLY MEAN ERROR FOR 120-HR 500 MB HEIGHT FORECASTS: NH102
NMC
ECMWF
MEAN HEIGHT ERROR (METERS)
50
40
30
20
10
0
-10
-20
-30
-40
-50
82 F M A M J J A S O N D 83 F M A M J J A S O N D 84 F M A M J J A S O N D 85

Figure 5c

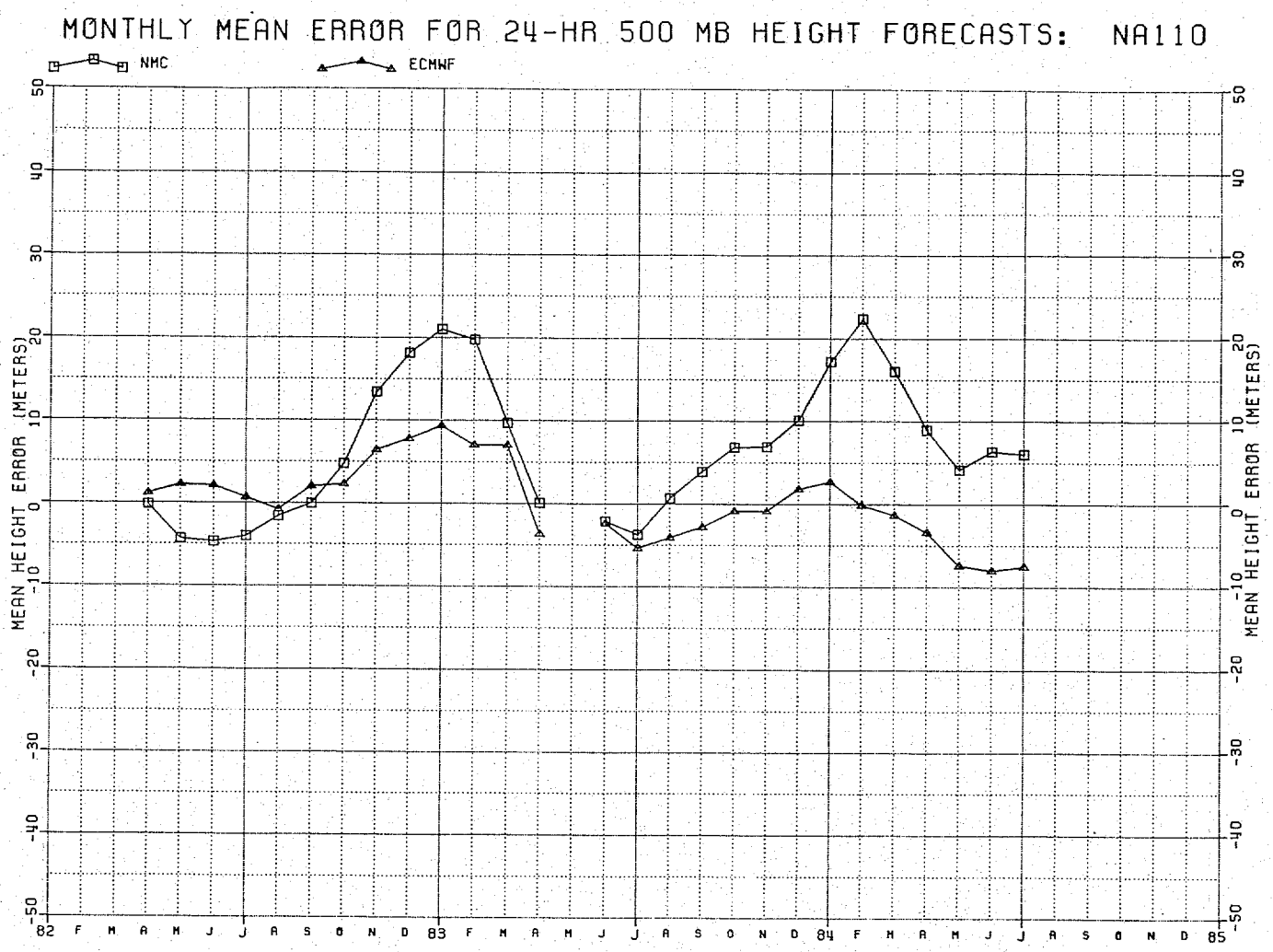
MONTHLY MEAN ERROR FOR 24-HR 500 MB HEIGHT FORECASTS: NA110
NMC
ECMWF
MEAN HEIGHT ERROR (METERS)
50
40
30
20
10
0
-10
-20
-30
-40
-50
82 F M A M J J A S O N D 83 F M A M J J A S O N D 84 F M A M J J A S O N D 85

Figure 6a

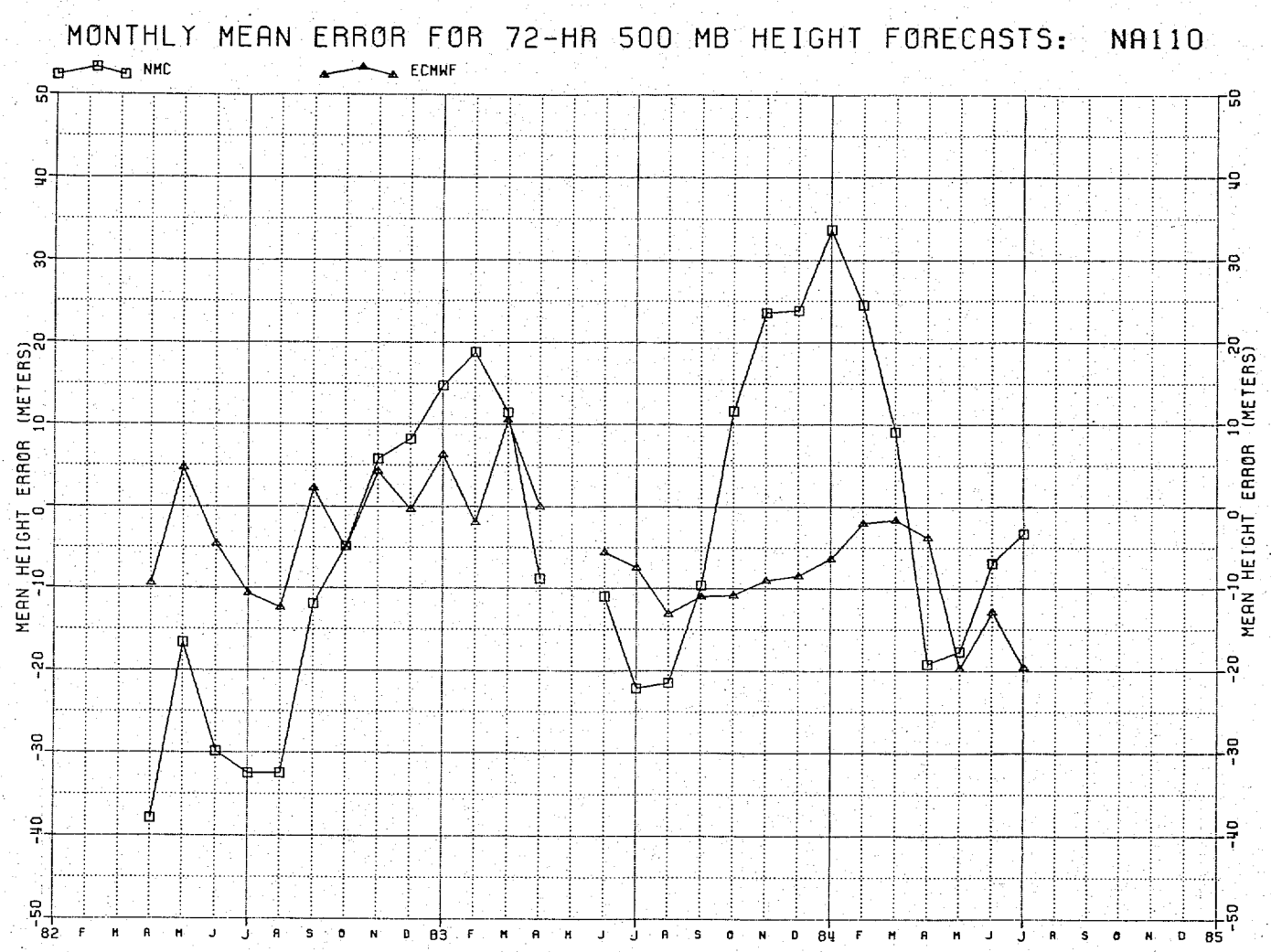
MONTHLY MEAN ERROR FOR 72-HR 500 MB HEIGHT FORECASTS: NA110
NMC
ECMWF
MEAN HEIGHT ERROR (METERS)
50
40
30
20
10
0
-10
-20
-30
-40
-50
82 F M A M J J A S O N D 83 F M A M J J A S O N D 84 F M A M J J A S O N D 85

Figure 6b

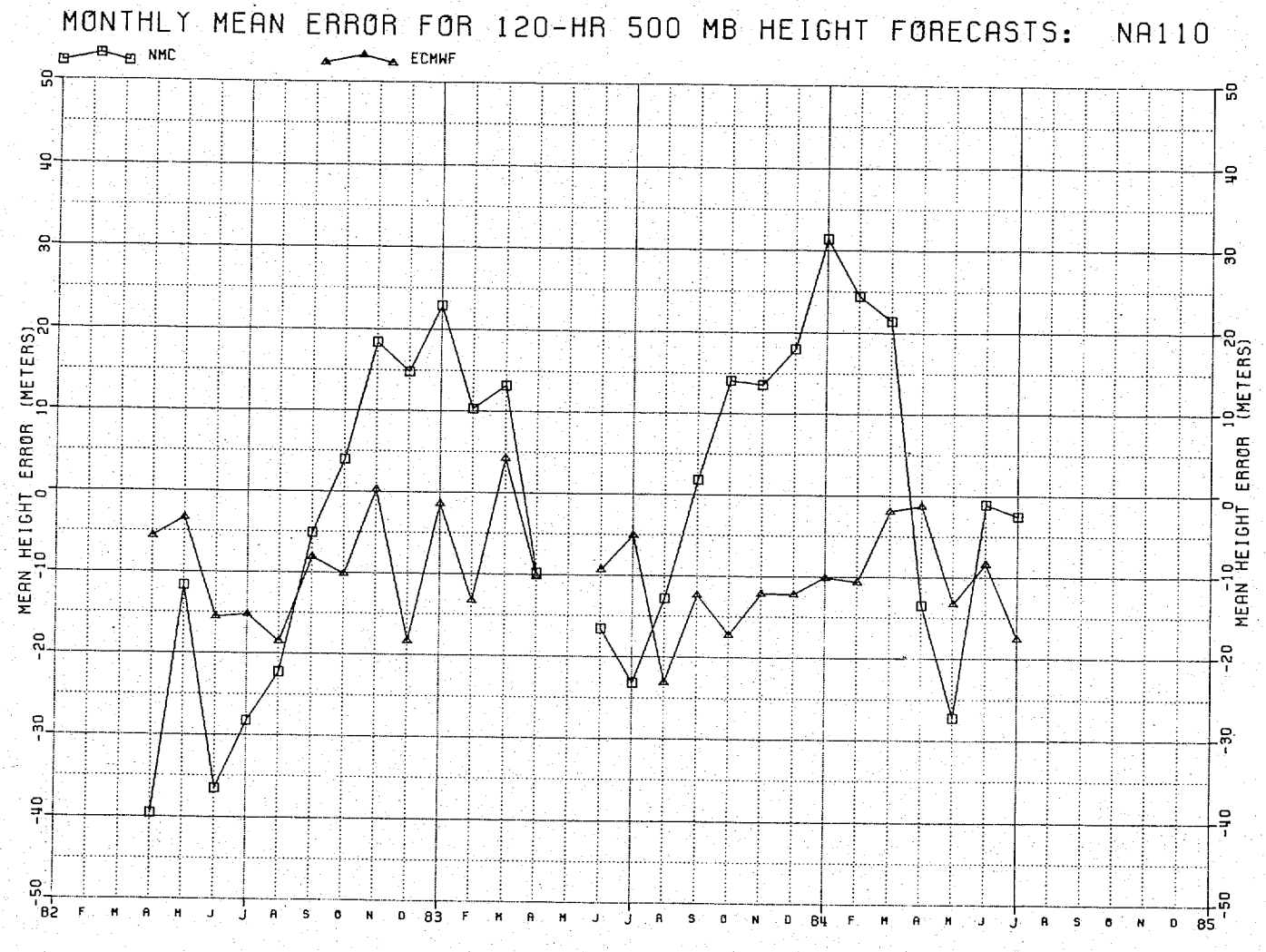
MONTHLY MEAN ERROR FOR 120-HR 500 MB HEIGHT FORECASTS: NA110
NMC
ECMWF
MEAN HEIGHT ERROR (METERS)
50
40
30
20
10
0
-10
-20
-30
-40
-50
82 F M A M J J A S O N D 83 F M A M J J A S O N D 84 F M A M J J A S O N D 85

Figure 6c

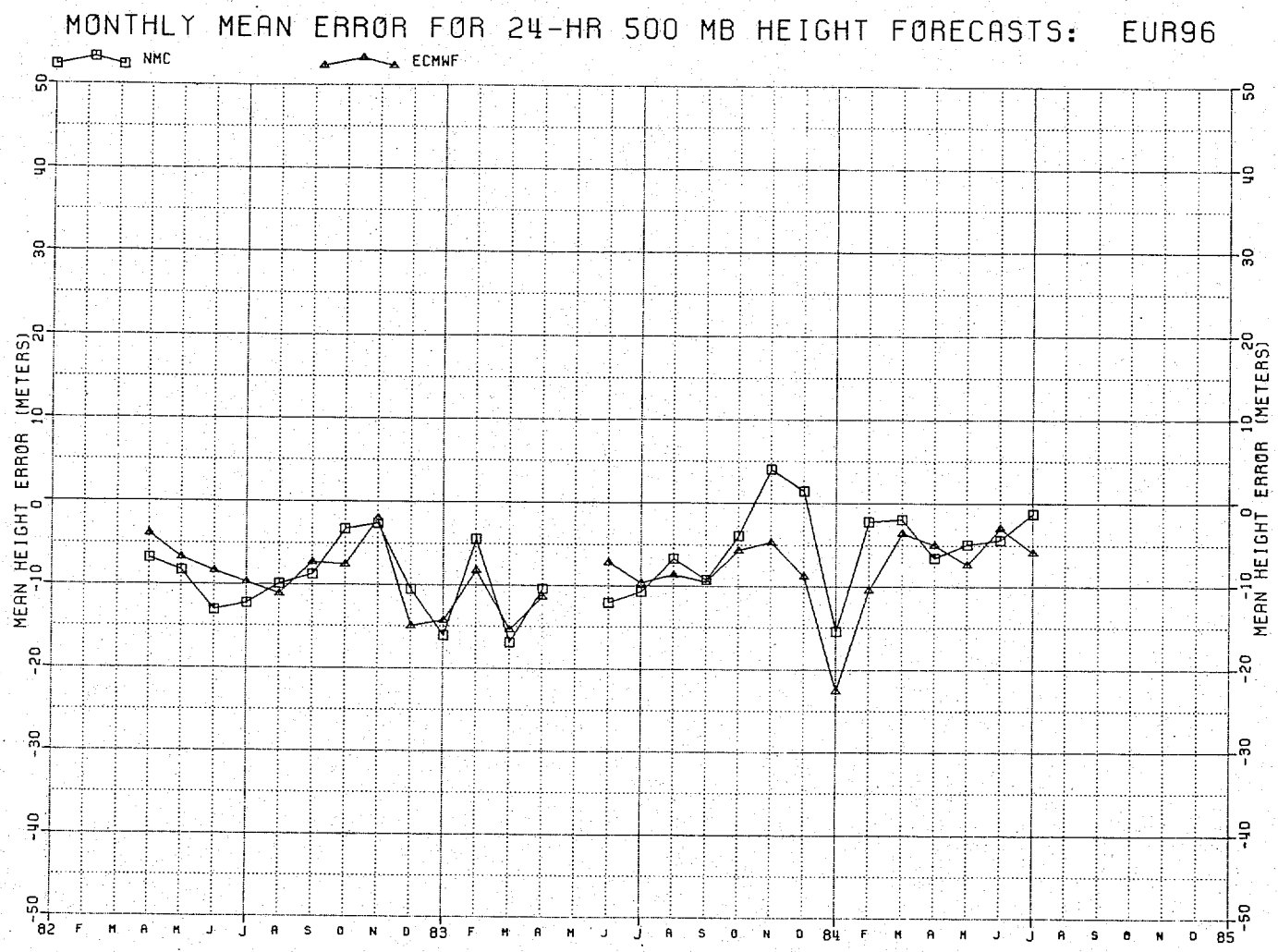
MONTHLY MEAN ERROR FOR 24-HR 500 MB HEIGHT FORECASTS: EUR96
NMC
ECMWF
MEAN HEIGHT ERROR (METERS)
50
40
30
20
10
0
-10
-20
-30
-40
-50
82 F M A M J J A S O N D 83 F M A M J J A S O N D 84 F M A M J J A S O N D 85

Figure 7a

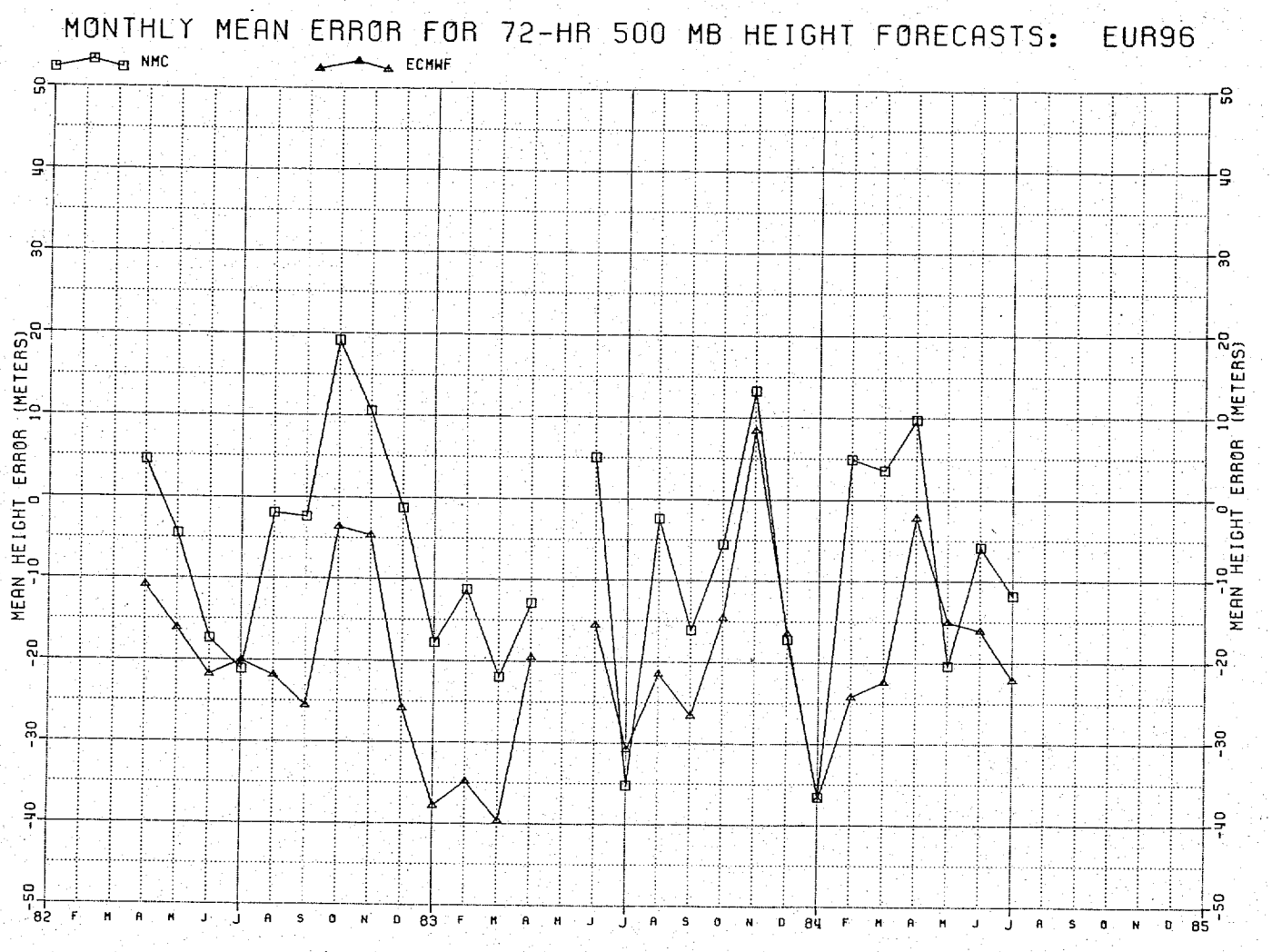
MONTHLY MEAN ERROR FOR 72-HR 500 MB HEIGHT FORECASTS: EUR96
NMC
ECMWF
MEAN HEIGHT ERROR (METERS)
50
40
30
20
10
0
-10
-20
-30
-40
-50
82 F M A M J J A S O N D 83 F M A M J J A S O N D 84 F M A M J J A S O N D 85

Figure 7b

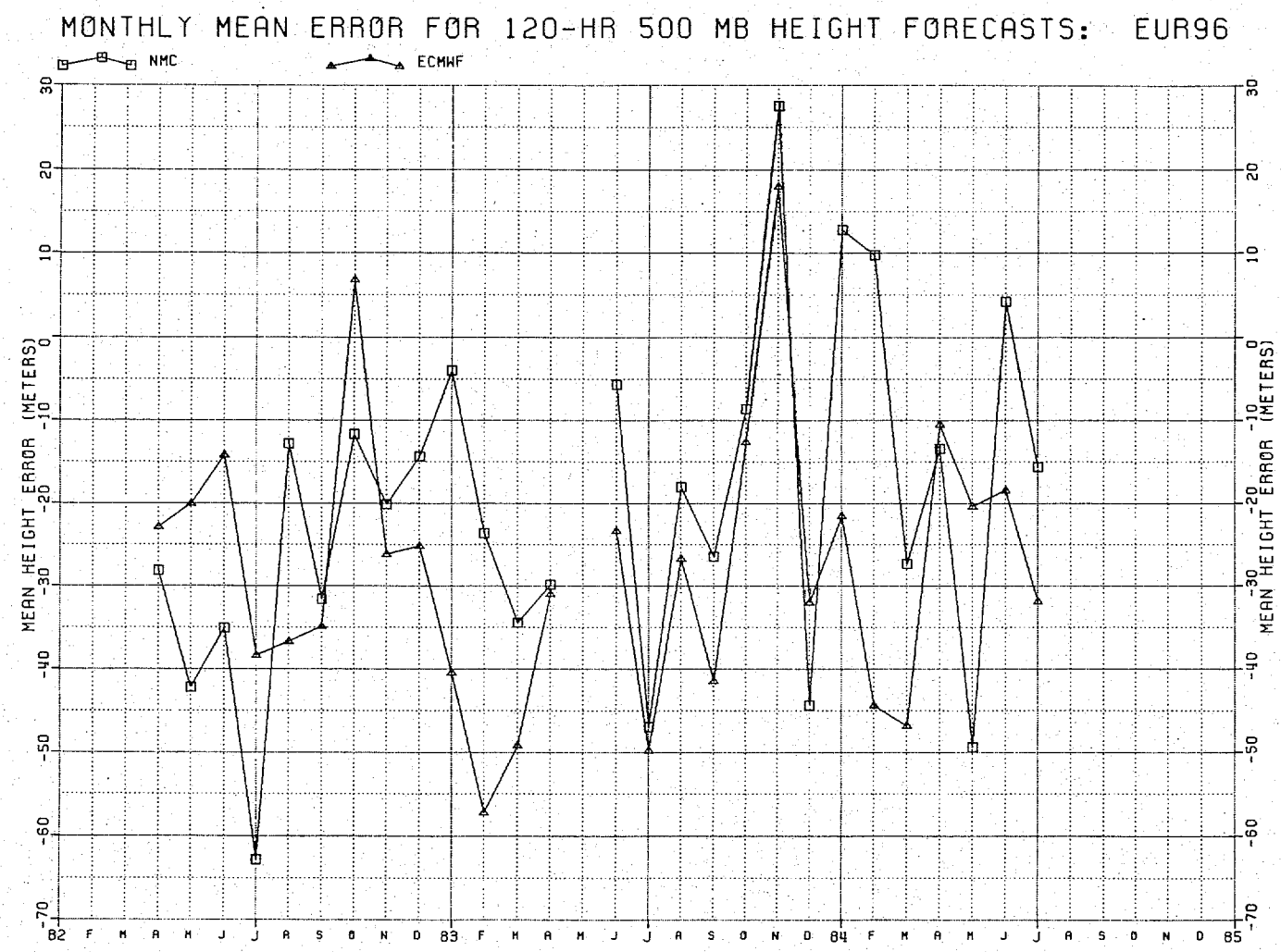
MONTHLY MEAN ERROR FOR 120-HR 500 MB HEIGHT FORECASTS: EUR96
NMC
ECMWF
MEAN HEIGHT ERROR (METERS)
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
82 F M A M J J A S O N D 83 F M A M J J A S O N D 84 F M A M J J A S O N D 85

Figure 7c

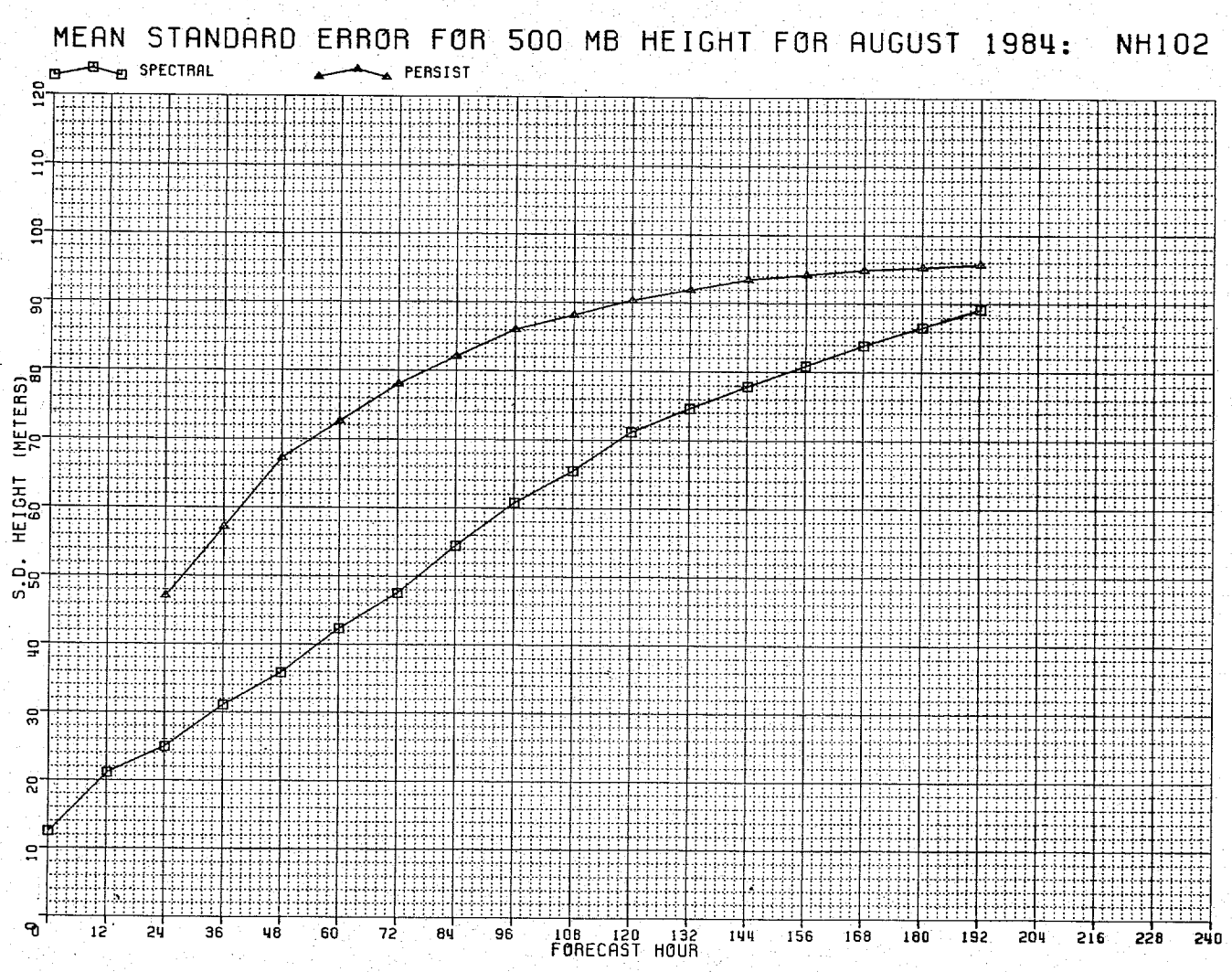
MEAN STANDARD ERROR FOR 500 MB HEIGHT FOR AUGUST 1984: NH102
SPECTRAL
PERSIST
S.D. HEIGHT (METERS)
0
10
20
30
40
50
60
70
80
90
100
110
120
12
24
36
48
60
72
84
96
108
120
132
144
156
168
180
192
204
216
228
240
FORECAST HOUR

Figure 8

MEAN DIFFERENCE (1ST YEAR - 2ND YEAR) OF STANDARD ERROR OF 500 MB HEIGHT
T-SCORE OF STANDARD ERROR DIFFERENCES BETWEEN NMC AND ECMWF MODELS
5% SIGNIFICANCE LEVEL: 2.07 1% SIGNIFICANCE LEVEL: 2.82

NH102	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5
NMC	-0.70	-0.68	-0.24	-0.85	-2.63
ECMWF	1.58	2.65	1.84	1.87	-0.03
T-SCORE	6.48	3.61	0.85	0.62	0.59

NA110	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5
NMC	-0.54	-2.14	-2.13	-3.63	-5.64
ECMWF	2.15	2.37	1.83	0.90	0.13
T-SCORE	7.77	4.70	1.48	0.78	0.89

EUR96	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5
NMC	0.23	-0.18	-0.55	-0.30	-4.01
ECMWF	0.97	0.48	0.02	0.00	-0.75
T-SCORE	0.92	0.33	0.07	0.02	0.12

TABLE 1