VERIFICATION OF ECMWF FORECASTS ON HEMISPHERIC AND REGIONAL SCALES IN THE FREE ATMOSPHERE

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ABSTRACT

Operational procedures in use at ECMWF to verify forecast fields in the free atmosphere are briefly reviewed, with some results for 1980 and 1981. Results from verification of ECMWF forecasts in the World Meteorological Organisation, Commission for Atmospheric Science (WMO-CAS) NWP data study and intercomparison project are also reviewed, again with comparisons between the results for 1980 and 1981. Verification of ECMWF forecasts by objective means in some other centres is discussed.

1. FIELD VERIFICATION AT ECMWF

1.1 Introduction; data-base, scores and areas

Operational verification of forecast fields at ECMWF has been carried out in its present form since January 1980 (Nieminen, 1982). The verification data base, which is stored on magnetic tape, is outlined in Table 1. The analyses against which the forecasts are verified are initialised, although uninitialised analysis fields for geopotential height and wind components from July 1981 are included in the verification data base.

The scores which are routinely computed are listed in Table 2. Figure 1 shows the areas over which the scores are computed. Note that besides the Northern Hemispheric (18° to 78° N), Southern Hemispheric (18° to 78°S) and tropical (18°N to 18°S) areas, there are twelve limited areas, which are chosen on the basis of the relatively good coverage of conventional (TEMP and PILOT) data available there, this leading to an increased confidence in the accuracy of the analysed fields in these areas.

The horizontal grid resolution used in computing the scores varies; a 3 x 3 degree latitude-longitude resolution is used in tropical and sub-tropical limited areas, a 3 x 6 degree resolution in the extra-tropical limited areas, a 6 x 6 degree resolution in the equatorial belt and a 6 x 9 degree resolution in the extra-tropical hemispherical areas. A latitudinal cosine weight is used to compensate for the decreasing grid interval in the meridional direction. For a full description of the data-base scores and areas, see Nieminen (1982). A selection of the results of the field verification (and of other statistics) are included in ECMWF Forecast Reports (1982), which are published quarterly.

VERIFICATION DATA BASE

$3^o \times 3^o$ Horizontal resolution; global fields

1000, 850, 700, 500, 300, 200 mb (from 1 Jan. 1980)

1000, 850, 700, 500, 300, 200, 100, 50 mb (from 1 Jan. 1981)

5 days/week to 1 August 1980

7 days/week later

Geopotential height

Temperature

Wind components

Relative humidity

Δt = 12 hrs. to H+48

Δt = 24 hrs. to H+240

Table 1: ECMWF operational verification data base; the grid-point values are extracted from the post-processed analysis and forecast fields.

Tendency correlation

Anomaly (deviations from climatology) correlation

Absolute correlation (for wind)

RMS error	For forecast and persistence
Standard deviation of error	
Mean error (bias)	
S1 skill score of height	

Table 2: Objective scores routinely computed in the operational field verification.

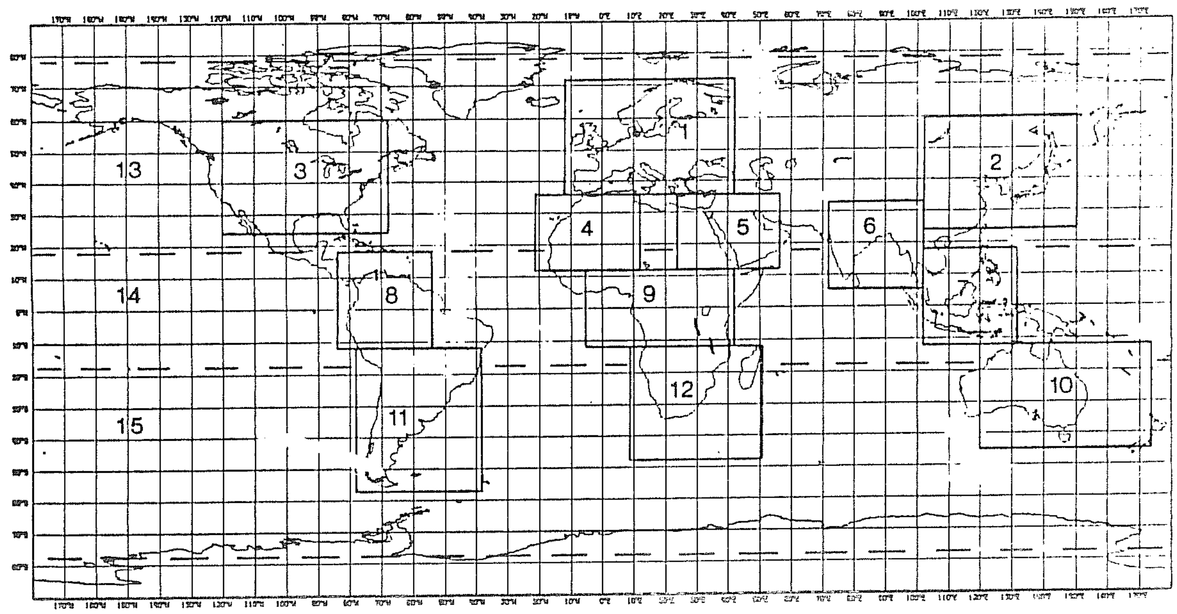

Figure 1: Areas used for the objective verification of operational forecasts.

1.2 Results

Figure 2 shows the mean height errors for winter (left) and summer (right) for the forecasts of 1981 for the Northern Hemisphere (top) tropical belt (middle) and Southern Hemipshere (bottom) in the model forecasts between 1000 and 50 mb and for H+12 to H+240 forecasts. The errors are negative in general, and are greatest in the extra-tropics for the winter season. The mean temperature errors (Figure 3) show a corresponding cooling of the model troposphere in all areas and seasons as the forecasts proceed. The areal distribution of the height errors in the D+3 and D+7 500 mb forecasts over the Northern Hemipshere is shown in Figure 4 (winter) and Figure 5 (summer); these figures are taken from the WMO CAS data study and inter-comparison project. The increase in the negative height errors near northwestern Europe and Alaska in winter shows a similar pattern at 1000 mb (not shown), although the amplitude of the error increases with height (Figure 2). Elsewhere over the hemisphere the errors are in general rather small. The errors in summer (Fig. 5) are smaller than those in winter.

The winter error pattern, in particular, is associated with the fact that depressions affecting northwestern Europe are too deep in the model climatology, and a southerly shift in the track of cyclones as they move eastwards across the continent of Europe. These errors have been noted as systematic synoptic errors in the forecasts. The error pattern, in its spatial distribution, shows great similarities between different models (Bengtsson and Lange, 1982). The mean height errors for limited areas for the winters of 1981 and 1982 (Figure 6) shows a lower error for the more recent forecasts, reflecting at least in part, improvements made to the operational forecasting system at ECMWF in the intervening months.

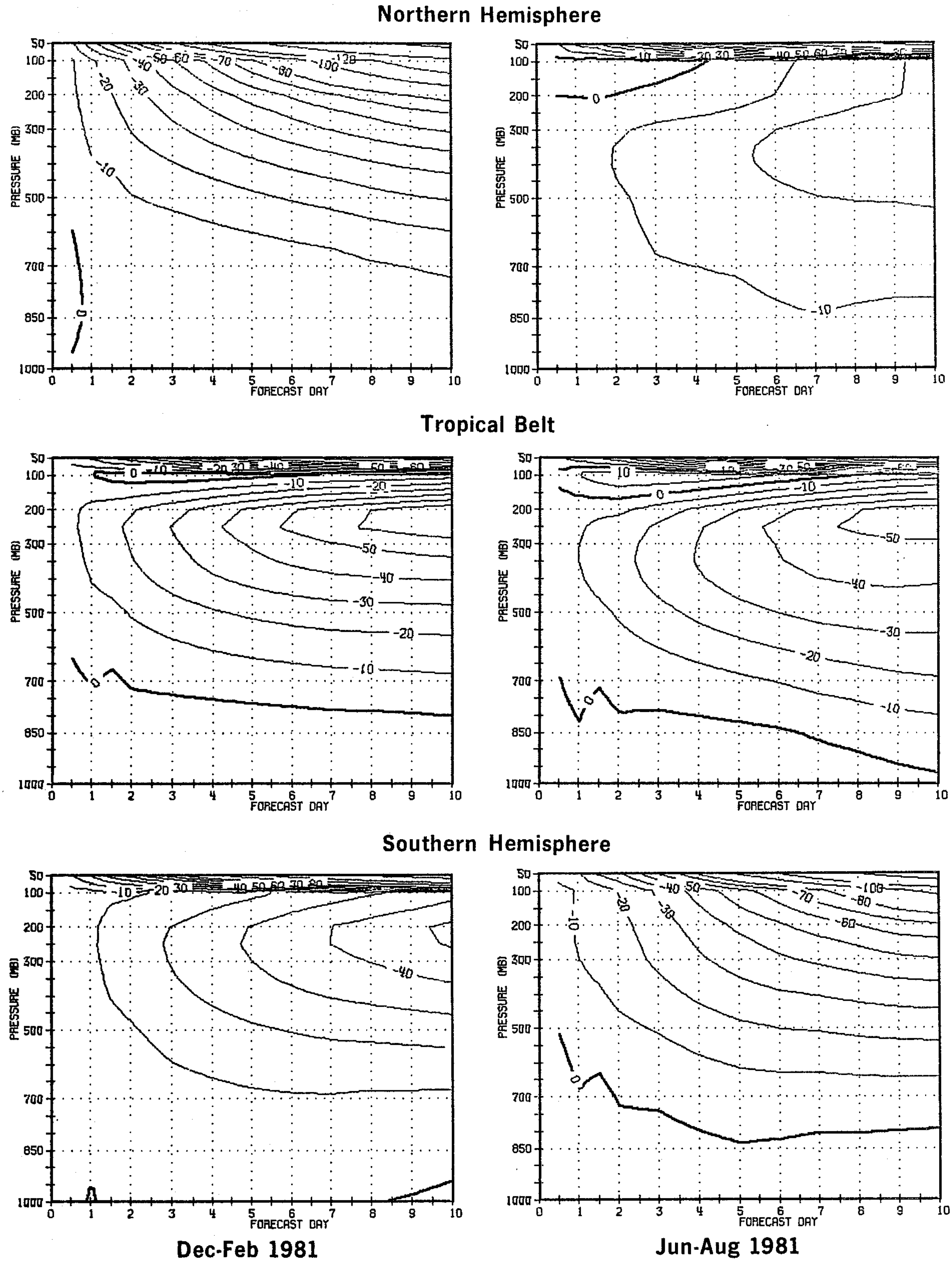

Fig. 2 Mean height error scores for 1000-50 mb and for forecasts from H+12 to H+240 for the areas of the Northern Hemisphere (18°N-78°N), Tropical Belt (18°N-18°S) and Southern Hemisphere (18°S-78°S).

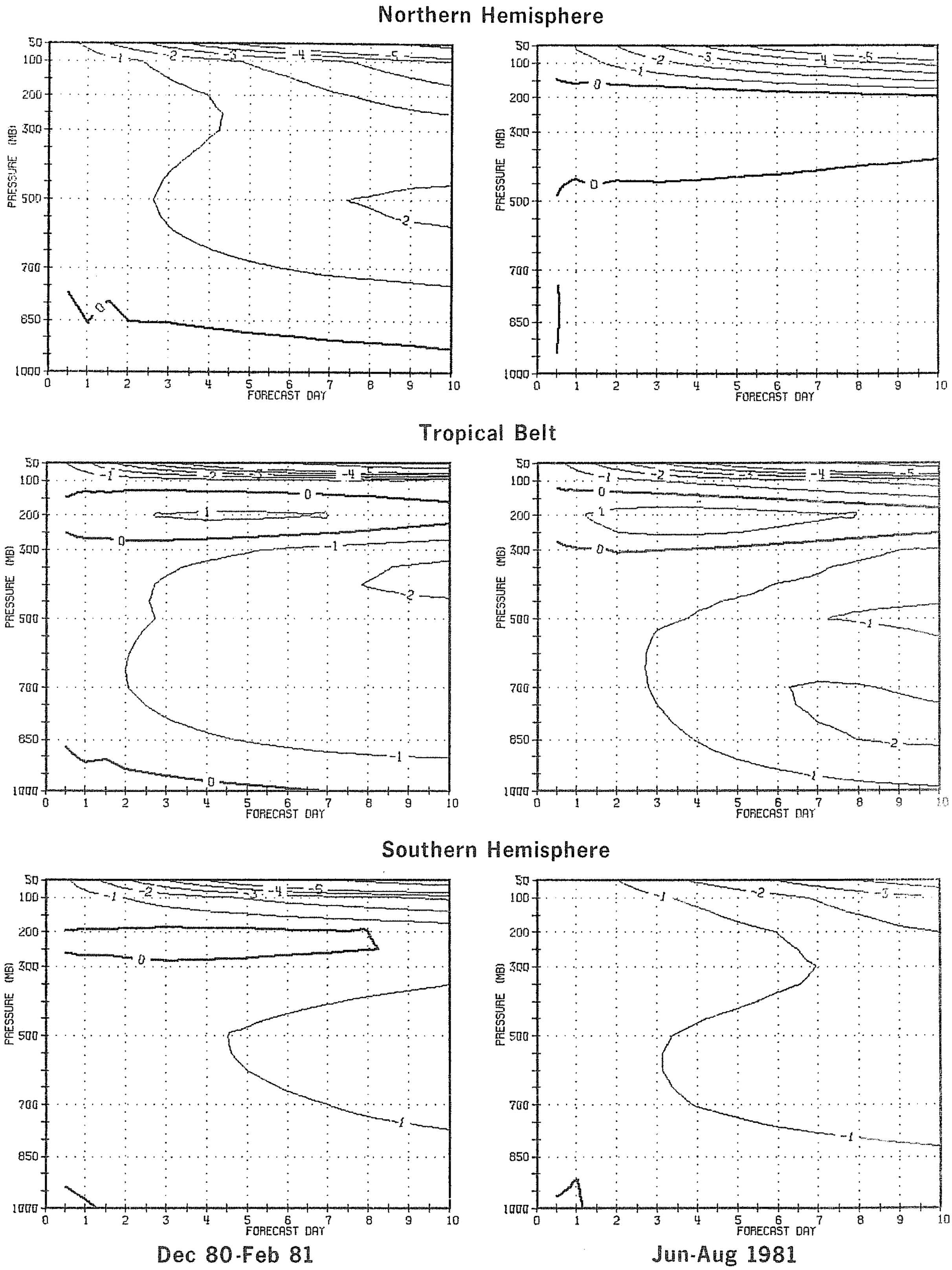

Fig. 3 As Fig. 2 but for temperature.

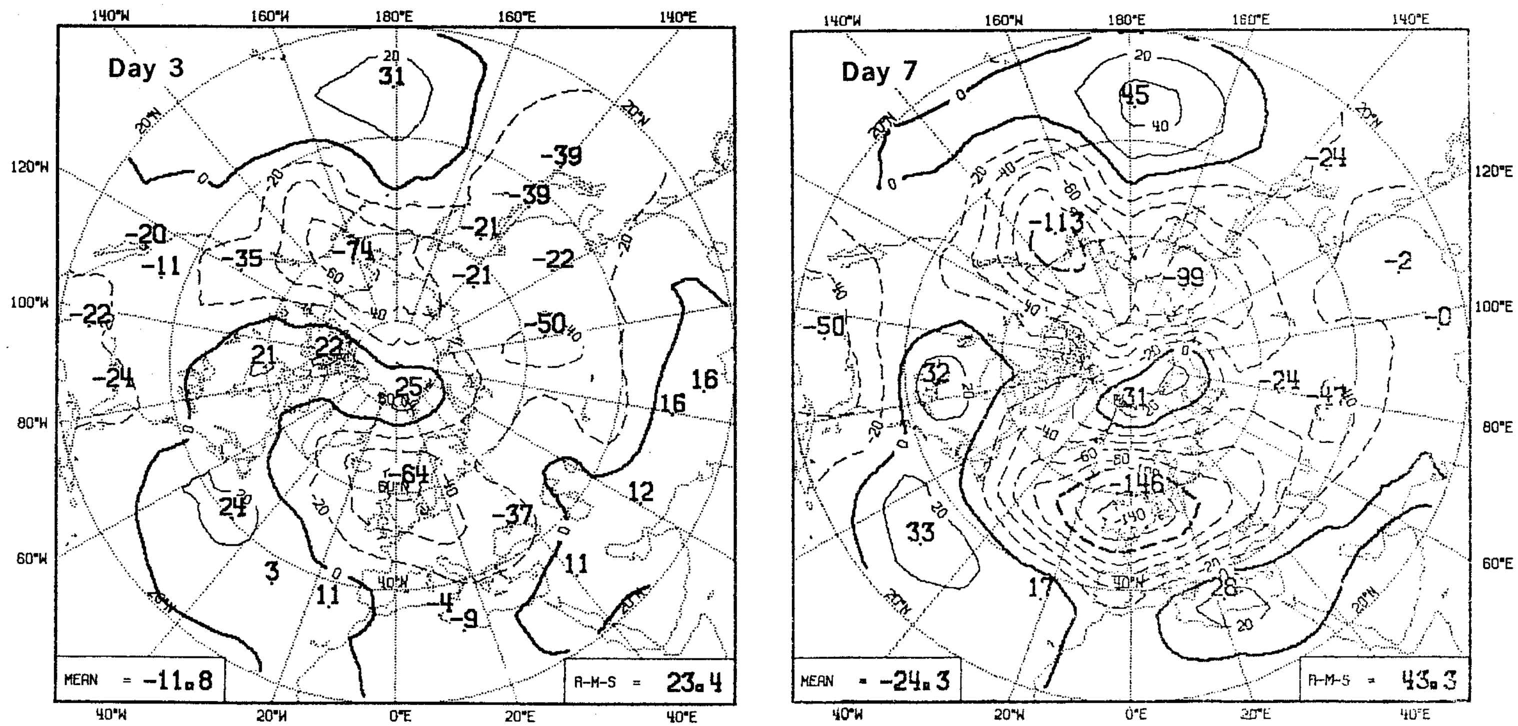

Fig. 4 Forecast Day 3 and Day 7 mean 500 mb errors for the first quarter of 1981 (1Q81).

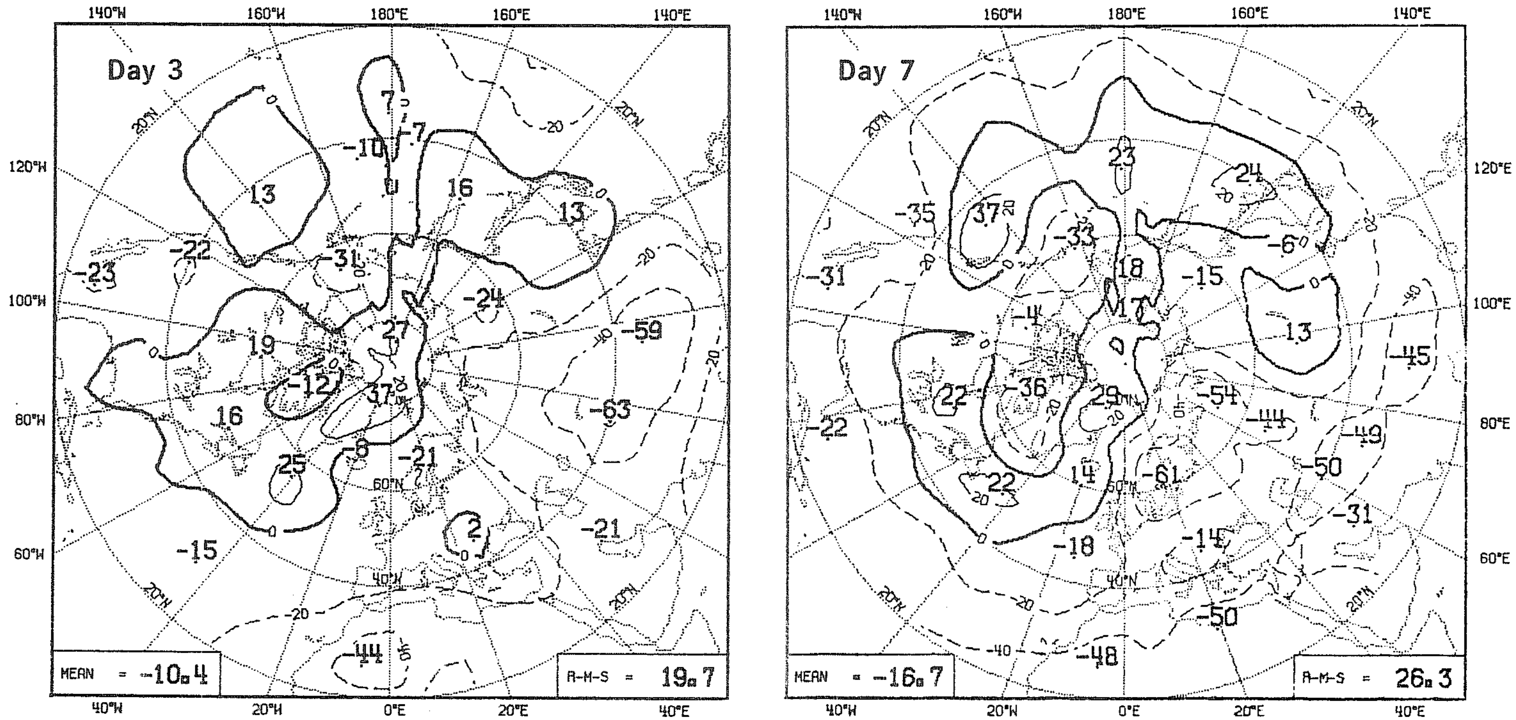

Fig. 5 As Fig. 4 but for 3Q81.

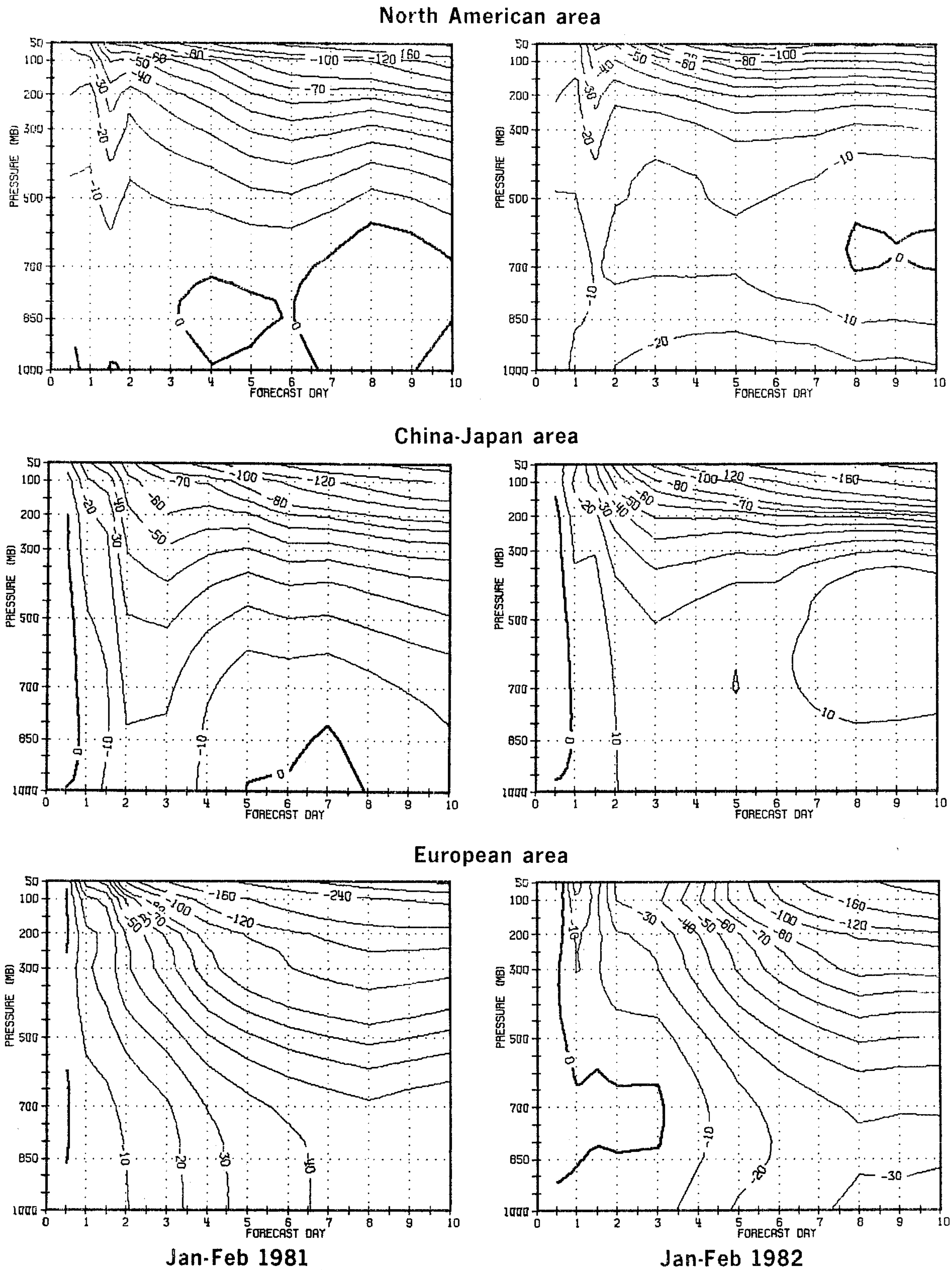

Fig. 6 Mean height error scores for 1000-50 mb and for forecasts from H+12 to H+240.

Anomaly correlation scores for three limited areas in the Northern Hemisphere (Figure 7) show notable differences in these scores for different areas and seasons. Using a 60% correlation (thick line) at the 500 mb level as a measure of forecast accuracy, the winter forecasts (left column) are better than the summer forecasts (right column) in the three areas. Differences between the three areas are notable; for the China-Japan area the forecasts have a score of above 60% at 500 mb until after D+7 in winter, compared with D+6 for North America and after D+5 for the European area. In summer, the differences between the three areas are much less. The large winter differences may be associated with differences in the climatology of the three regions, with the greater systematic error over Europe (Figure 4) also contributing to the relatively low scores for this region.

2. RESULTS FORM THE WMO-CAS NWP DATA STUDY AND INTERCOMPARISON PROJECT; 1980 AND 1981 SCORES COMPARED

Figure 8 shows the standard deviation of the 500 mb height for D+3 forecasts of January to March 1980 and 1981. Figure 9 shows the same score for July to September 1980 and 1981.

Looking at the mean and root-mean-square values of the standard deviation scores, we see that lower scores, especially for the winter forecasts, are found for 1981. The areal distribution of the scores is roughly similar for the two years (and also similar to that of the scores of the forecasts from other Centres (not shown)) with the highest winter values in the Pacific near the west coast of Canada, and with another relative maximum in the Atlantic to the south of Greenland.

In summer, the Atlantic maximum is shifted northwards, probably in association with the seasonal northward shift in the tracks of Atlantic depressions. The magnitude of the scores are everywhere lower in summer than in winter; this can also be seen clearly in Figure 10 where the root-mean-square of the standard deviation of the D+3 forecasts are plotted for seven major forecast centres, including ECMWF, for all quarterly periods where available from 1Q79 to 4Q81. Note also in this figure the steady improvement in the ECMWF forecasts; compare for example the scores for 4Q79, 4Q80 and 4Q81. The improvement in the already low summer errors is not so marked.

The mean errors of the winter 1980 and 1981 forecasts (Figure 11) show an overall reduction for the 1981 forecasts, although the systematic negative maximum centred near 60°N 0°E increased. The spatial distribution of the mean error pattern has been discussed in section 1.2 above. The mean error scores for the summers of 1980 and 1981 are shown in Figure 12; lower errors are again observed for the 1981 forecasts.

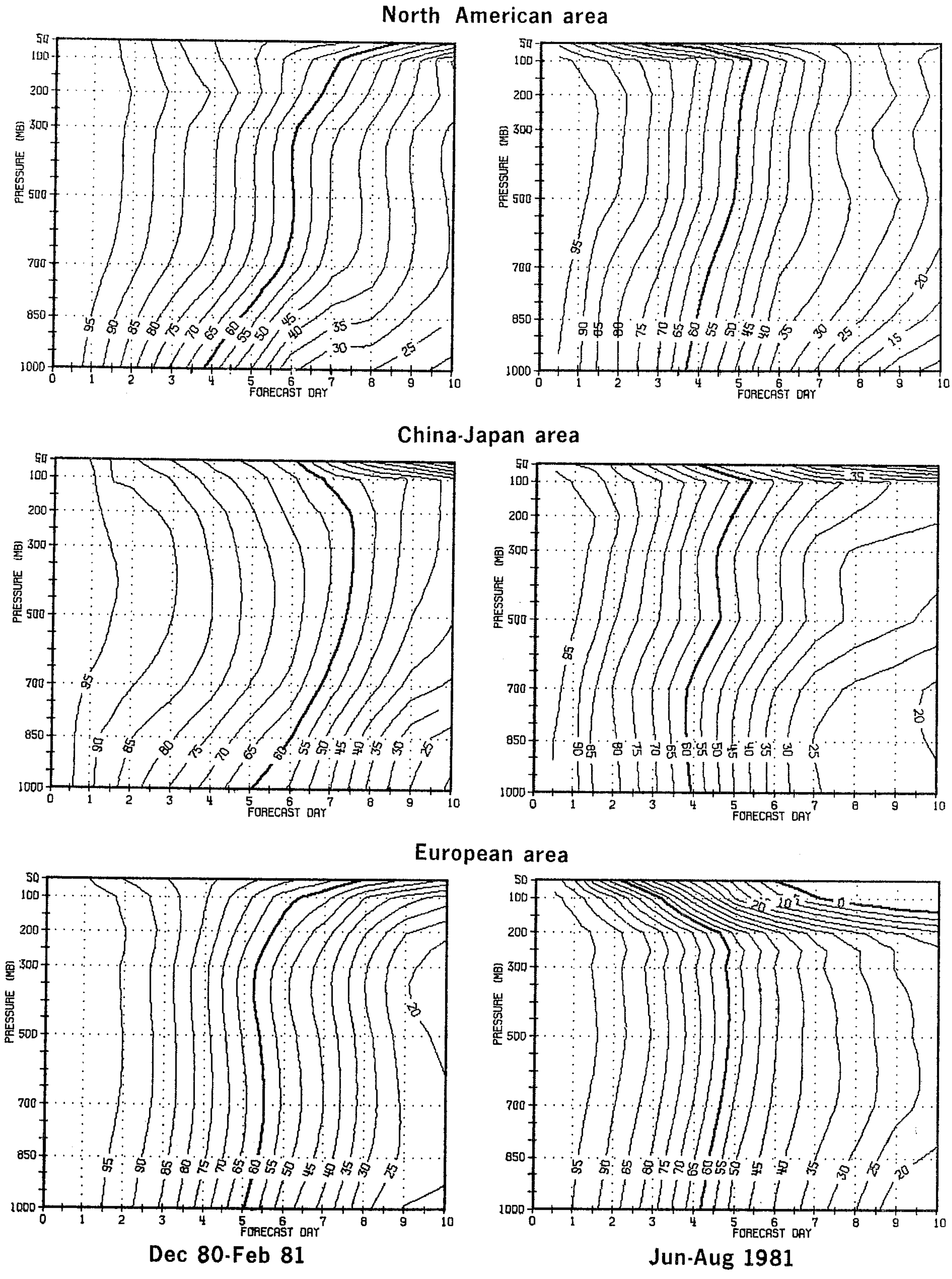

Fig. 7 Anomaly correlation of height scores for 1000-50 mb and for forecasts from H+12 to H+240.

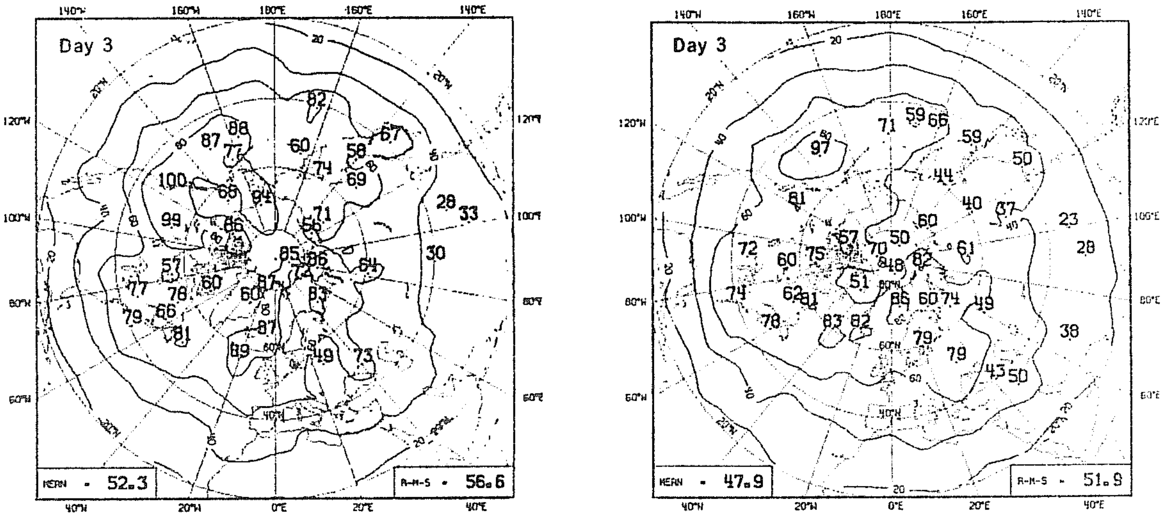

Fig. 8 Standard deviation scores for ECMWF forecasts for 1Q80 (left) and 1Q81 (right).

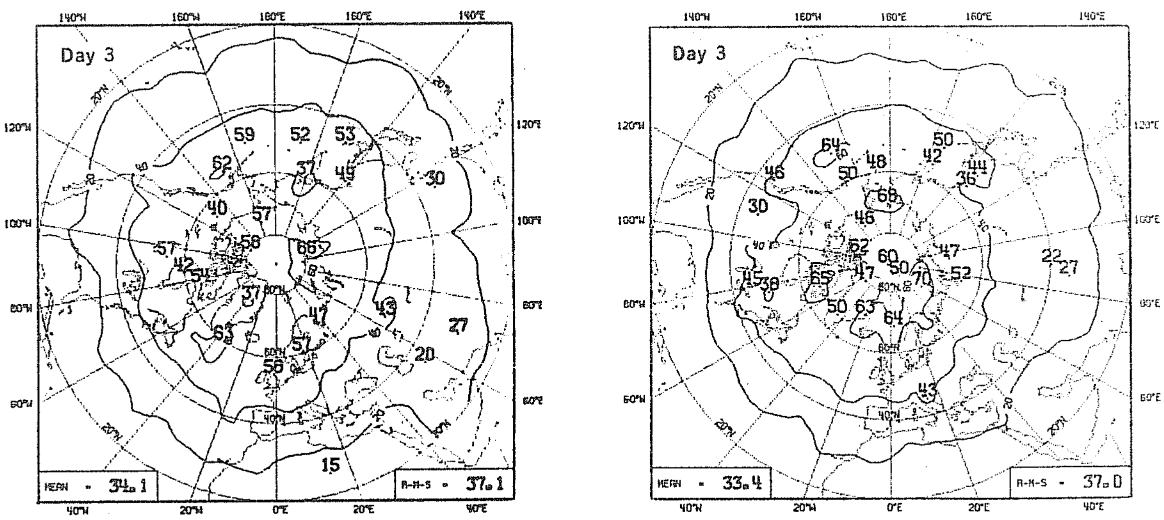

Fig. 9 As Fig. 8 but for 3Q80 (left) and 3Q81 (right).

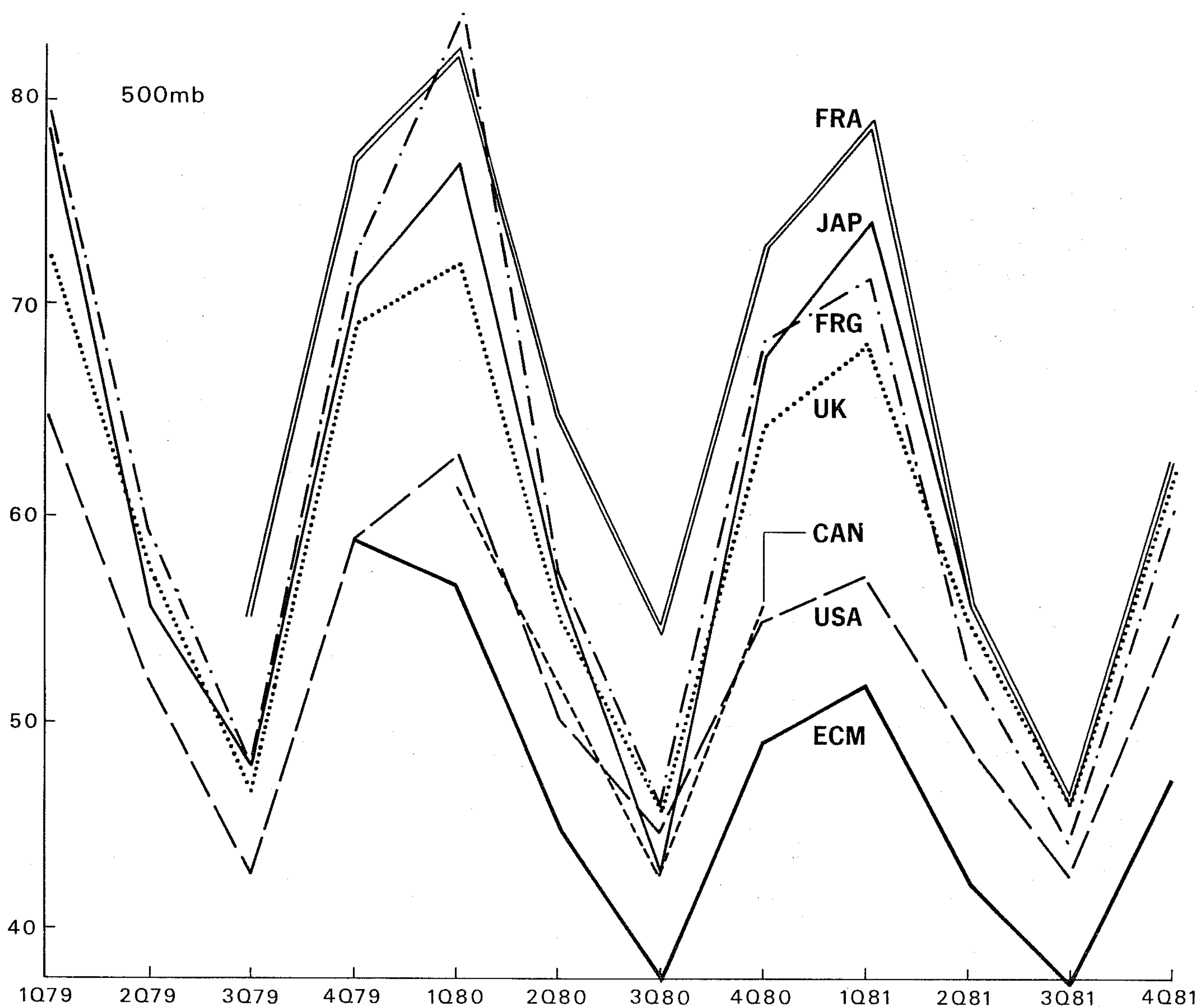

Fig. 10 RMS of standard deviation for the Northern Hemisphere, Day 3 forecasts from 1Q79 to 4Q81 (where available) from ECMWF and other Centres.

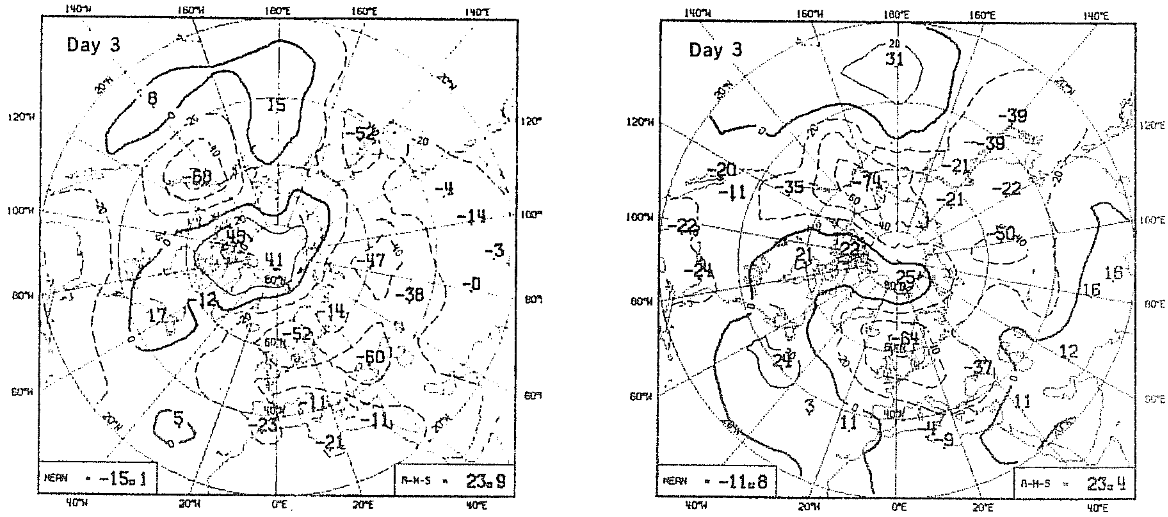

Fig. 11 ECMWF mean errors at 500 mb for forecasts for 1Q80 (left) and 1Q81 (right).

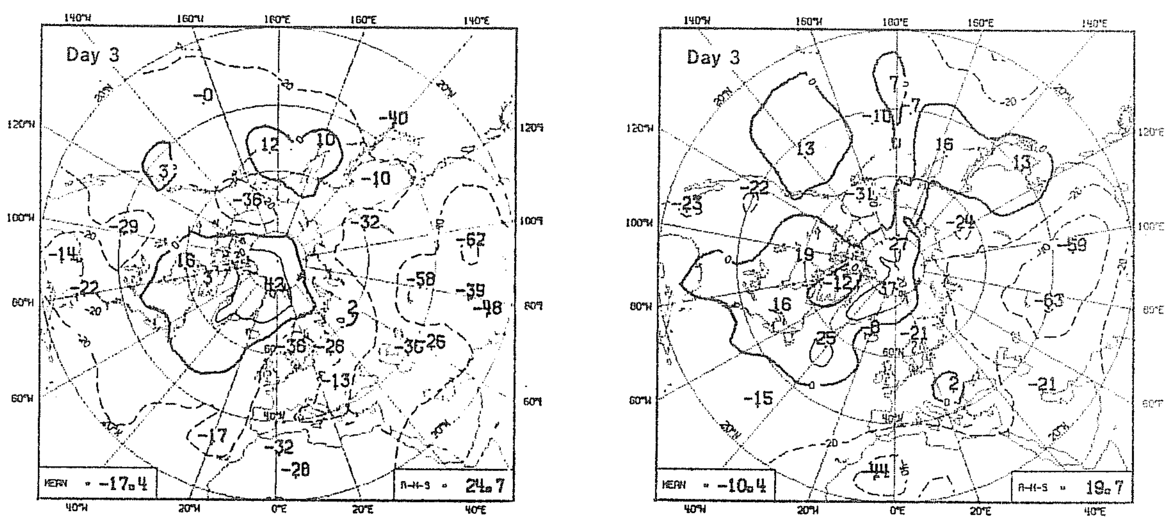

Fig. 12 As Fig. 11 but for 3Q80 (left) and 3Q81 (right).

3. VERIFICATION OF ECMWF FORECASTS AT SOME OTHER FORECASTING CENTRES

3.1 Netherlands

Each month, verification scores are published by the Royal Netherlands Meteorological Institute (KNMI) in a Verification Bulletin (1982). The scores include comparison scores of ECMWF, United Kingdom Meteorological Office, NMC Washington and KNMI forecasts. Some of these scores are shown plotted in graphical form in Figure 13. UKMO and NMC forecasts are roughly comparable in performance, the ECMWF forecasts maintain a consistent lead over the others.

3.2 Greece

ECMWF forecasts are verified in Greece over an area which includes parts of Europe, North Africa and the eastern Mediterranean (Kakouros and Rafene-Katsimardos, 1982). The number of grid points used in 12 x 10; RMS errors, tendency correlations and relative errors are computed. The relative error is defined as

$$\frac{\sum_{i=1}^{m} f_{in}-f_{il}}{\sum_{i=1}^{m} f_{io}-f_{il}}$$

where the subscripts n,l and o refer to forecast, actual and initial values respectively of the parameter f. The RMS error and tendency correlation scores are computed from standard formulae. Verification scores for 3Q81, 4Q81 and 1Q82 are shown in Figure 14.

3.3 Hong Kong

ECMWF 1 to 5 day forecasts of 500 mb height are verified at the Royal Observatory, Hong Kong. Verification is against upper-air data from about 50 radiosonde stations in an area including Japan and parts of China ($20^{o}$to 60^{o}N, 90^{o} to 160^{o}E). Scores of the forecast and of persistence are computed; those of the months November 1981 to June 1982 are shown in Figure 15.

3.4 United States of America

Since February 1982 NMC has been receiving the 24 through 120 hour ECMWF forecasts of 500 mb height and sea level pressure on a near real time basis over the GTS on a 5^{o} latitude-longitude grid for the Northern Hemisphere north of 20^{o}. These are biquadratically interpolated to NMC's "standard" 65 x 65 polar stereographic grid for display and verification purposes. The relative skill of ECMWF versus NMC forecasts has been assessed objectively; the results of the NMC evaluations through April 1982 are given below.

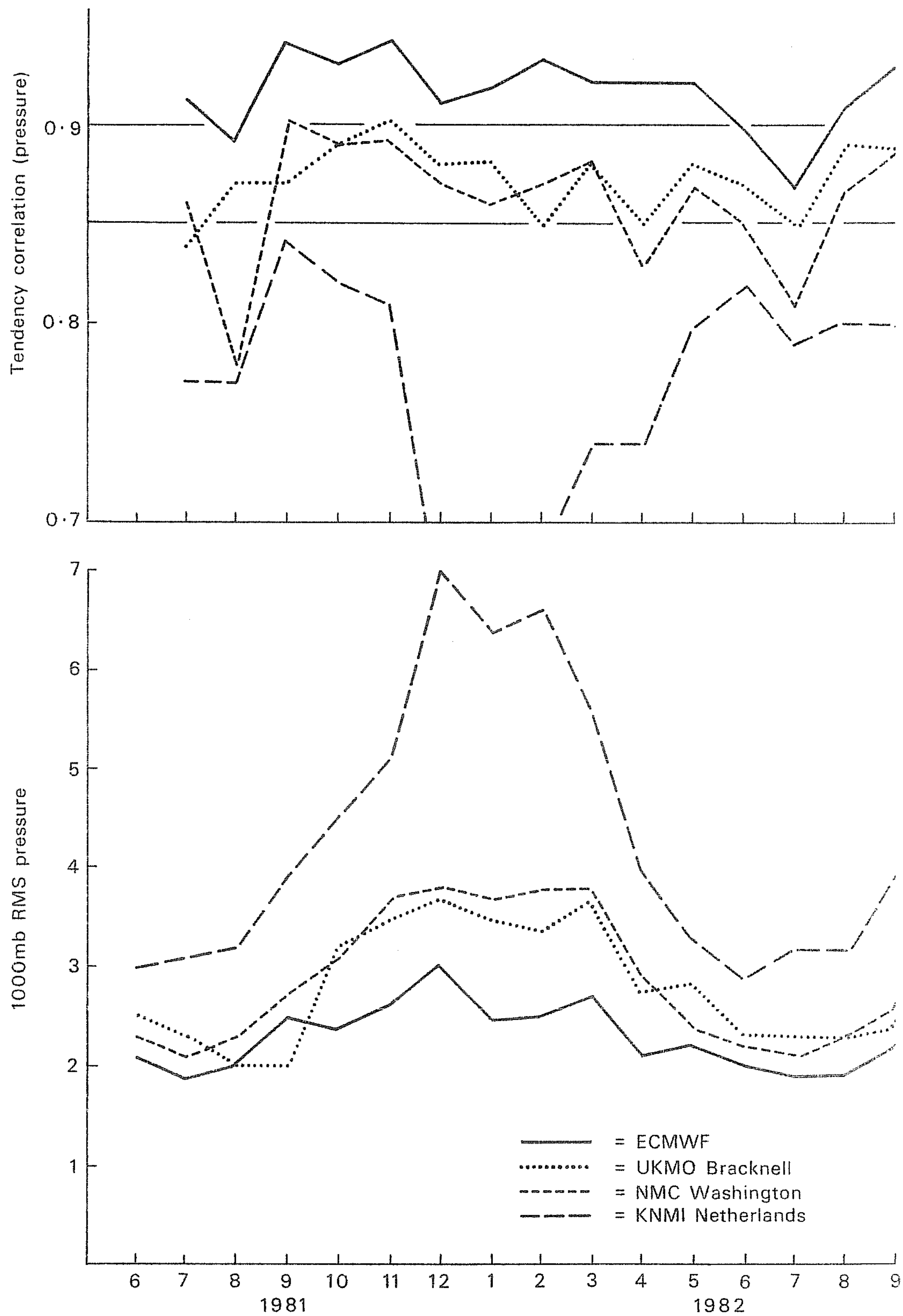

Fig. 13 Tendency correlation (top) and RMS error (bottom) of surface pressure forecasts for ECMWF, UKMO, NMC Washington and KNMI forecasts computed at KNMI Netherlands.

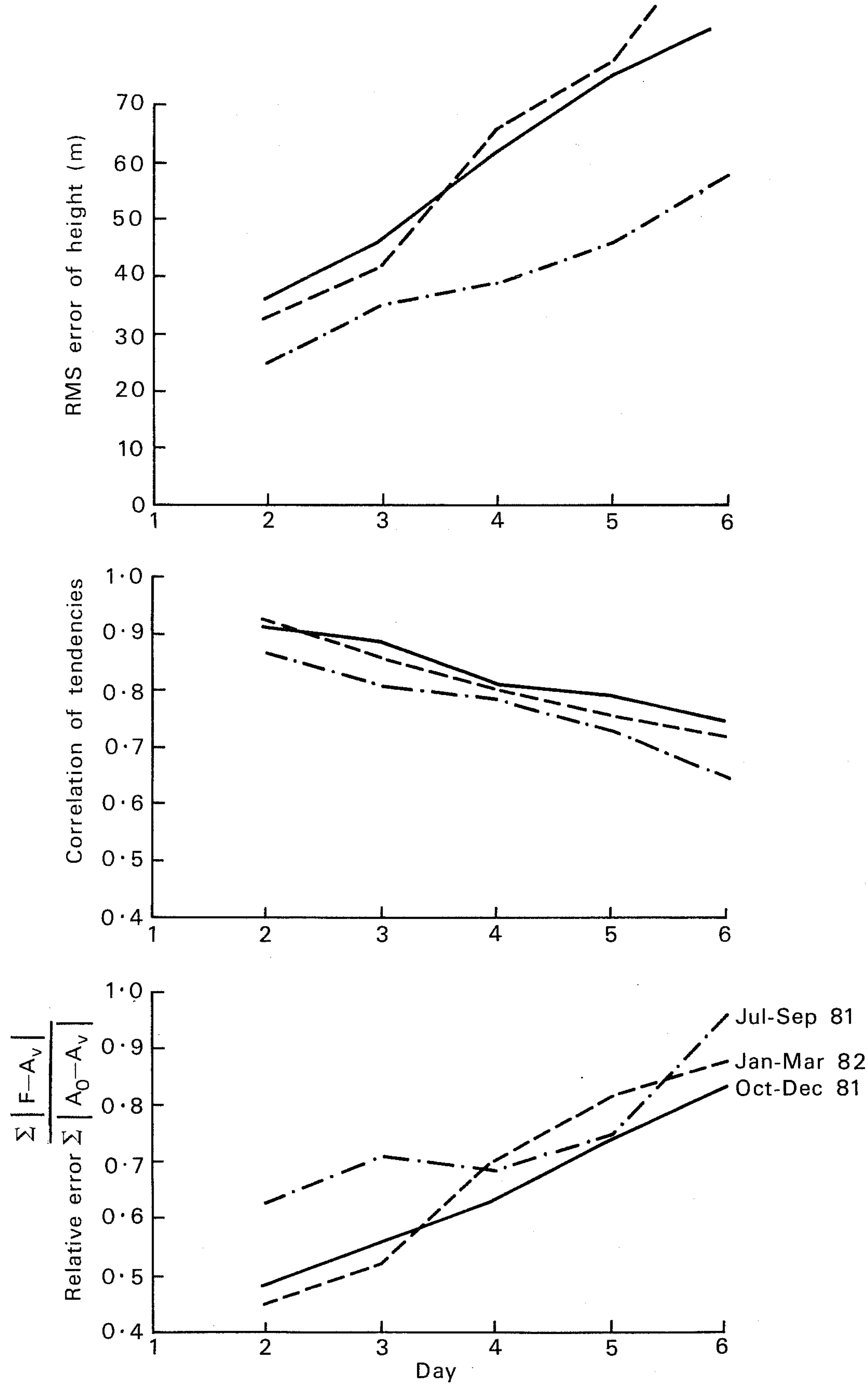

Fig. 14 Scores of ECMWF 500 mb forecasts for the Eastern Mediterranean area computed at the National Meteorological Service of Greece.

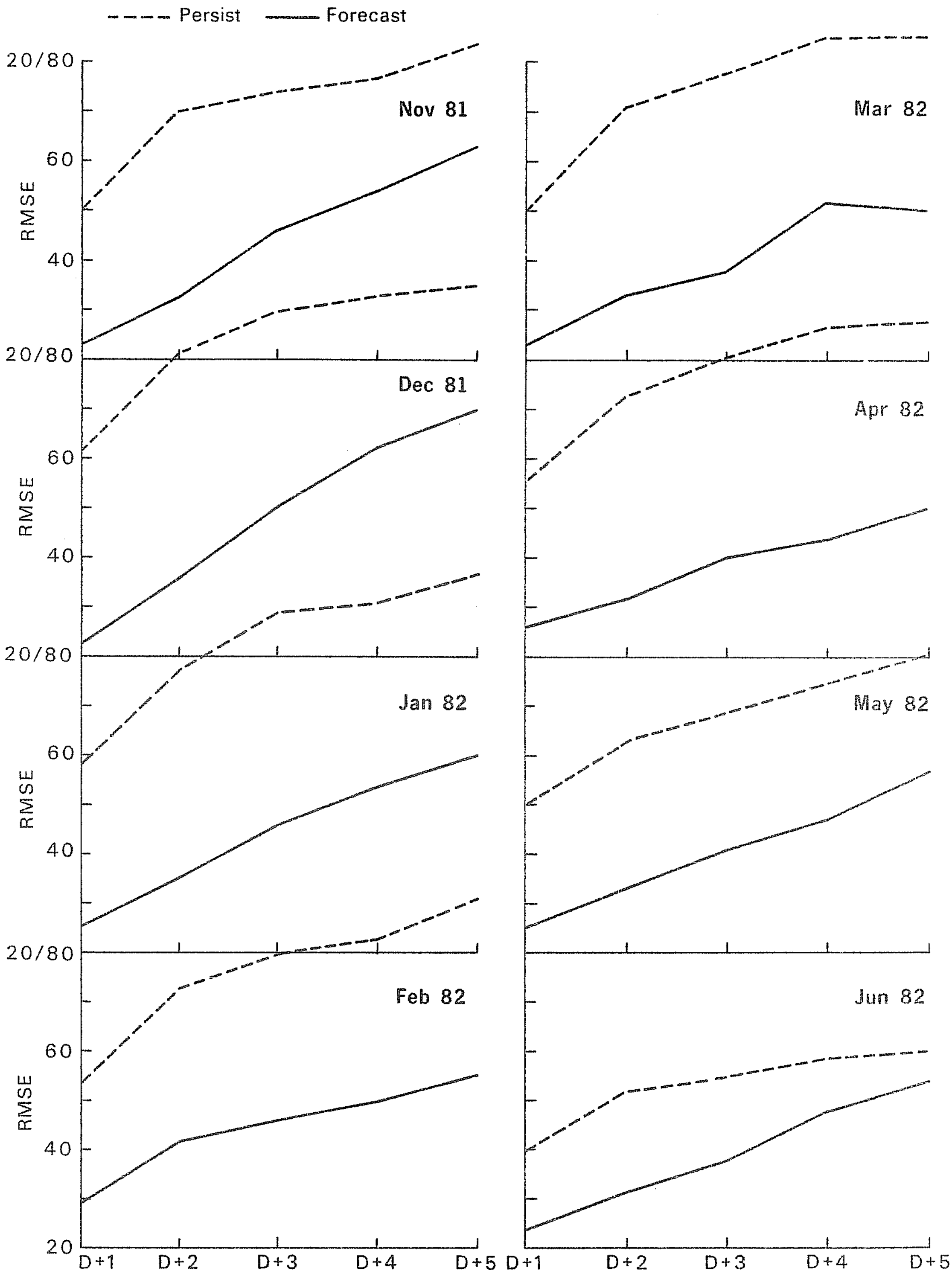

Fig. 15 RMS error of ECMWF 500 mb forecasts at 1200 GMT for the period November to June, for an area centred near Hong Kong, computed at the Royal Observatory of Hong Kong.

Comparative objective verifications of the ECMWF model and NMC's spectral model forecasts of 500 mb height are presented in Figure 16, The particular verification statistic shown here is the standard deviation of the error of the 500 mb heights plotted as a function of forecast hour. For the spectral model (solid lines) the statistic is plotted every 12 hours up to 48 hours and is for all the forecasts (averaged) for the month; after that time forecasts from the 00z initial time (the only ones made) are, naturally, the only ones considered. The ECMWF model scores (dashed lines) are the monthly means for the once per day forecasts made from the 12z initial time and plotted every 24 hours - the only times available.

The calculation of these statistics is done by comparing the forecast field in questions with verifying radiosonde observations for a quasi-uniformly distributed selection of 102 RAOBS over the Northern Hemisphere. Figure 16 shows that, in general, the errors in ECMWF forecasts of 500 mb height are lower by 10-15% than those of the current NMC spectral model. This is equivalent to about a 12-hour difference in skill between the two global systems.

SUMMARY AND CONCLUSIONS

Verification results for ECMWF forecasts have been presented for the years 1980 and 1981, from verification procedures within ECMWF, from verification carried out by the WMO-CAS NWP data study and intercomparison project and from verification of ECMWF forecasts at other forecasting centres.

The results indicate in general that ECMWF forecasts are the most accurate available operationally and that there has been an improvement in the forecast quality from 1980 to 1981.

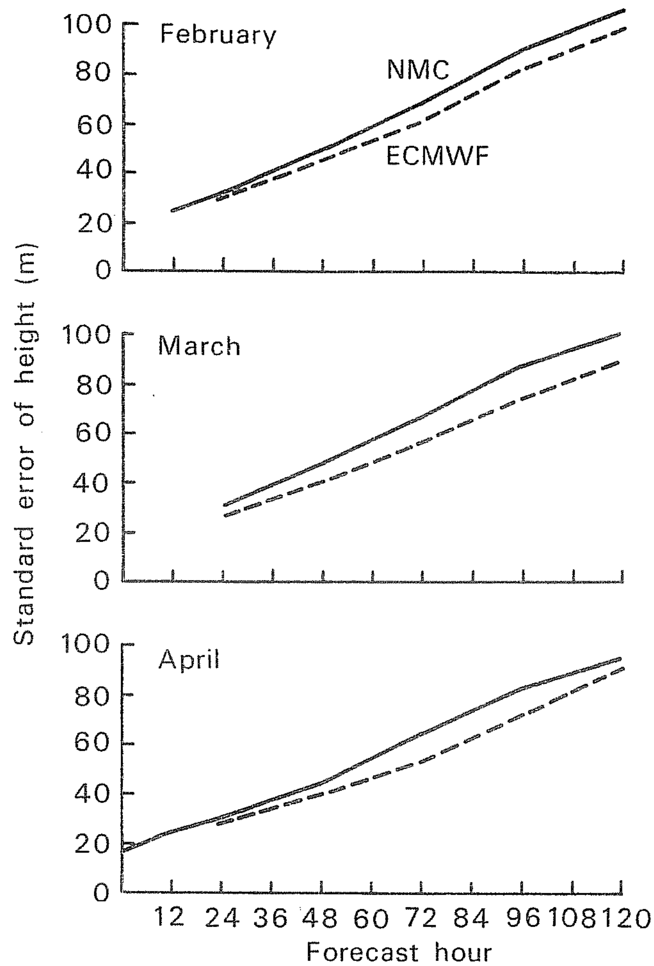

Fig. 16 Standard deviation of the error of 500 mb height for NMC and ECMWF forecasts at Feb-April 1982, computed at the National Meteorological Centre, Washington, USA.

REFERENCES

Bengtsson, L. and Lange, A., 1982: Results of the WMO-CAS NWP data study and intercomparison project for forecasts in the Northern Hemisphere in 1979-80. CAS Working Group on weather prediction research, WMO.

ECMWF, 1982: ECMWF Forecast Reports, quarterly, 35pp.

Kakouros, A. and Rafene-Katsimardos, M., 1982: Subjective and objective assessment of the products of ECMWF. Manuscript available from ECMWF.

KNMI, 1982: Verification Bulletin. Monthly, 4pp.

Nieminen, R., 1982: Operational field verification procedure at ECMWF with applied results for 1980-81. ECMWF Technical Report in preparation.