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NUMERICAL MAPPING AND MODELLING AND THEIR APPLICATIONS TO PRIME

COST 238/PRIME Workshop

Eindhoven, The Netherlands
1994

OVERVIEW

The volume contains a selection of papers presented at the May 1994 COST 238 Workshop on 'Numerical mapping and modelling and their applications to PRIME'. It is a pleasure once again to be associated with a full PRIME Workshop - this time the sixth in a series extending over as many years. PRIME (Prediction and retrospective ionospheric modelling over Europe) was formally initiated as Project COST 238 in March 1991 as a four-year project aimed at developing improved models of the European ionosphere for telecommunications applications, but the work has its origins earlier arising from existing collaborations in the areas of vertical and oblique-incidence sounding. We now have active participation from groups within 18 Western and Eastern European countries and again all were represented at this latest Workshop.

COST (Cooperation in Scientific and Technological Research) was initially established for European Union Member States, with each country joining those projects in which it has interest on a case-by-case basis. However, over recent years the numbers of COST countries have grown and there is now provision for participation of individual institutes from non-COST countries. In our case we have three such institutes involved.

The Workshop gave prominence to progress in developing NEW empirical mapping techniques along lines first proposed at a limited Workshop held in Abingdon, UK in December 1993. Following tests by specially appointed computer experts who had been assessing the relative accuracies of various candidate approaches the previous week in Eindhoven, latest developments were considered. Discussions centred on what further improvements could be incorporated. Subsequent to a successful specialist Workshop on instantaneous mapping which took place in Warsaw in March 1994, this topic was also addressed at length and a number of optional approaches considered.

The work of PRIME as a whole covers the topics of vertical and oblique-incidence sounding, short-term and long-term ionosphere mapping and modelling and short-term forecasting of ionospheric characteristics. Some 30 presented papers addressed different aspects of these subjects. In addition there were 9 poster papers. As always, time constraints limited full review of every facet, but by restricting the numbers of presented papers to invited topics it became possible to identify the key points and to take important decisions on the way ahead. I am grateful to Dr Leon Kamp and to the Working Group Leaders for their help in formulating the Workshop programme.

Each Session Chairman and Working Group Leader has provided a summary covering the ensuing discussion. Thanks should be extended to all who contributed to the Workshop both in preparing presentations and in participating in the discussions. I believe that in a very full programme optimum use was made of the available time and that good and timely overall progress is being made towards our agreed goals.

We are all particularly grateful to Dr Kamp on behalf of the Eindhoven University of Technology for hosting us and for the painstaking way in which he made the local arrangements. We extend our sincere thanks to him and his colleagues for all they did to ensure the event was a success. We especially thank Professor F W Sluijter and the University for hosting an accompanying social excursion and dinner.

Thanks are accorded to the University, The Netherlands Foundation for Fundamental Research on Matter, Océ van der Grinten, Stichting Universiteitsfonds Eindhoven, PTT Research and to the European Commission for financial support in making the meeting possible. Finally too our thanks go to Dr Kamp for arranging this present publication.

Peter A Bradley
Chairman COST 238

The December 1993 NEW mapping meeting

by

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W Singer, Th D Xenos and B Zolesi

1. Introduction

A meeting of the above WG-5, WP-2 participants concerned in the generation of new (NEW) mapping procedures for monthly median foF2 and M(3000)F2 took place at the Rutherford Appleton Laboratory over the period 8-10 December 1993. The meeting gave consideration to available measurement data for use for mapping, agreed the data set to be adopted, made plans for different consortia to undertake a series of separate mapping exercises and formulated a work timetable to meet the project deadline of having methods available for testing by 31 March 1994. It had been the intention to compare the separate mapping options within the group prior to submission but unavoidable delays in compiling the mapping data set precluded this possibility. In the event therefore a number of different candidate approaches have been forwarded. This paper reviews the conclusions reached at the meeting and their background and gives some brief details of certain of the methods that have been produced.

2. The mapping data set

It was confirmed to base the mapping data set only on monthly median values derived from the network of synoptic vertical-incidence ionosonde stations. Figure 1 shows those stations which PRIME had agreed should be used for map generation and those intended to be reserved for testing. We reviewed this decision and introduced some changes. Note that in the figure Bekescsaba and Budapest are shown combined since these data sets are mutually exclusive in time and their geographical separation is small.

The PRIME choice of stations for map generation was dictated to a significant degree by data availability on the timescale needed, since testing is a later activity. Whilst it is evident that as far as possible the same stations should not be used for map generation and testing, it is clear that other considerations are also important: there needs to be an adequate quantity of data for a given station to be useful, these need to be in digitised form and they should provide a satisfactory geographical coverage. Inspection of Fig.1 where four quarter PRIME areas are delineated reveals the particular paucity of data for the SW quadrant. At the time of the December meeting the Tortosa data (25) identified for testing were not digitised, there were very few data available for El Arenosillo (7) and very few also for Lisbon (16). We therefore decided that we must use Tortosa data in our map generation and the necessary digitisations were undertaken.

Bradley (1993a, 1994) from a study of the long series of measurements for Slough had confirmed that all available data should be used combined in the mapping irrespective of whether for the rising or falling parts of a cycle and without regard for from which solar cycle they came. From results of Kouris et al (1993) it was agreed that the solar-cycle mapping should be in terms of twelve-monthly smoothed sunspot number R and that a parabolic dependence with foF2 and a linear dependence for M(3000)F2 would be taken.

Table 1 shows the maxima and minima in R for the different solar cycles over which measurement data exist. There is little change in minima but big differences in maxima. The 'typical' cycle may be regarded as ranging from 10 to 160.

Cycle Years	maximum	minimum
1932-44	119	3
1944-54	152	8
1954-64	201	3
1964-76	111	10
1976-86	164	12
1986-97	158	12

Table 1: Maxima and minima is R over different solar cycles

So it is convenient to group the measurement data into three epoch bands corresponding to low ($R<60$), medium ($60<R<110$) and high ($R>110$) conditions. Table 2 indicates for the different stations and months the number of years of data already digitised within each such epoch band. It is evident that some stations have not made measurements over a sufficient number of years to cover all bands and in certain cases data relate to sunspot maximum when R was less than 110 for many months. Supposing that a minimum of 5 years of observations are needed in a given epoch band to be useful in determining the solar-cycle law, those stations meeting this criterion already digitised or potentially available in hard-copy form from the World Data Centres are given in Table 3.

Hence, without resources for large-scale digitisation of World Data Centre data it has been necessary to exclude from consideration for mapping the stations of Bekescsaba/Budapest, Lisbon, St Peter Ording and South Uist. De Bilt has also been excluded because there are digitised data only for one epoch band not in all months and this station is relatively close to Dourbes. Inconsistencies with Freiburg data led to this station also being excluded. So for mapping we have used the 11 stations indicated in Fig.1(b).

3. Analysis procedure

A linear relationship requires two anchor points and a parabolic dependence needs three points for its specification. Here the solar-cycle dependence of foF2 has conveniently been quantified for each station, month and hour by reference values within the low, medium and high epoch bands at R = 35, 85 and 160. In the case of M(3000)F2 it has been given from the values for R = 35 and 160.

To determine the reference values for M(3000)F2 best-fit linear regression lines have been fitted to the combined measurement data for all available years. With foF2, however, where the fit is more critical, use has been made of an indirect approach which relies on consistency between stations at a given hour and month to yield what are believed to be more accurate reference values for those stations with limited years of measurements. In this way it has been possible to maximise the meaningful station coverage, and not to have to discard data for some stations as has been the case in former mappings by some organisations. It is revealed (see the examples of Fig. 2 - other months and hours examined give similar findings between stations) that the fractional increase over the solar cycle is essentially independent of location. Therefore whilst for those stations having 5 or more years of data in each of the three epoch bands best-fit parabolic regression lines have been separately determined, when for a given station, hour and month this condition is not met in all such bands, the best-fit mean parabola over all stations has been applied with an amplitude scaling factor. The meeting gave particular consideration (Bradley, 1993b) as to whether it was necessary to apply ponderation (weighting) factors in these regression analyses to take account of uncertainties in median estimates in cases of incomplete daily sampling but this was discounted in view of the limited number of data sets where this could be important, also noting the additional analysis complexity involved.

Let $foF2 = a + bR + cR^2$
and $M(3000)F2 = d - eR$

Then if Ω_1, Ω_2 and Ω_3 are the values of foF2 for R = 35, 85 and 135 respectively, and if Ω_4 and Ω_5 are the values of M(3000)F2 for R = 35 and 135 respectively we have that:

$$a = 2.295\,\Omega_1 - 1.890\,\Omega_2 + 0.595\,\Omega_3$$
$$b = -0.044\,\Omega_1 + 0.068\,\Omega_2 - 0.024\,\Omega_3$$
$$c = 0.0002\,\Omega_1 - 0.0004\,\Omega_2 + 0.0002\,\Omega_3$$
$$d = 1.35\,\Omega_4 - 0.35\,\Omega_5$$
and $$e = 0.01\,(\Omega_4 - \Omega_5)$$

T D Xenos, assisted by M I Dick, has determined Ω_1 - Ω_5 for all months and integer local-time hours for all the stations to be used in the mapping and made this data set available among the consortia on floppy disk. Whilst for foF2 generally c is slightly negative providing something of an effective saturation at the higher R (Fig.3), there are a few cases with more negative c where a peak is indicated below R = 200. These latter are regarded as an unrealistic representation and for R above the maximum are replaced by the constant peak value. Positive c first shown by Sizun (1991) giving upwards bending curves are also occasionally found.

4. Mapping methods

Using the above Ω data sets plans were made for 7 separate mapping initiatives with different participants taking the lead in each of these. In every case the mapping was to be an empirical formulation covering the dependence on time-of-day, month and location. Firstly there were to be new versions of SIRM, PASHA and EOF. Then the Kriging program was to be applied to generate values on a 5° latitude-longitude grid of 45 locations. For each of these locations there are stored 5 Ω values x 12 months x 24 hours, making 64,805 data values in total. The evaluation method involves quadratic geographical interpolation among this data set.

Bradley and Dick (1993) have shown (Fig.4) that the diurnal variation expressed in local time about the 24-hourly mean for a given month is essentially independent of location and this can be represented by separate hourly values together with Fourier interpolation for non-integer times. Furthermore, the 24 hour mean foF2 is as approximately linear function of latitude (Fig.5) and shows no discernible longitude dependence. M(3000)F2 has no systematic latitude variation (Fig.6) and is taken to be completely independent of location. Total storage involves 1476 data values. A variant method with secondary longitudinal effects also quantified has been abandoned, since there are no evident trends within available data sampling. A separate mapping which relies on a linear latitude dependence at each local time but is not constrained to the same diurnal variation at all latitudes involves storage of some 2904 data values. Initial accuracy assessment tests were conducted in Eindhoven by a special testing team and results are reported elsewhere; further tests are planned for El Arenosillo.

References

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foF2 L: R12 < 60 M: R12 60–110 H: R12 > 110

	JAN			FEB			MAR			APR			MAY			JUN			JUL			AUG			SEP			OCT			NOV			DEC		
	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H
UPPS	12	8	8	11	9	8	11	10	7	11	10	7	11	9	7	11	9	7	11	9	7	10	9	6	10	9	7	10	8	8	11	7	9	11	8	8
SOUT	2	0	2	3	1	2	3	1	2	2	1	2	3	1	2	3	1	2	3	1	2	3	0	2	3	0	2	3	0	2	3	0	2	3	0	2
KALI	12	8	6	12	9	6	12	9	6	12	9	6	12	9	6	11	9	6	11	9	6	12	9	6	11	10	5	11	9	6	12	7	7	12	8	5
JULI	13	7	6	12	8	6	12	8	6	12	8	6	12	8	6	12	8	6	12	8	6	12	8	6	11	9	6	11	8	7	12	6	8	12	7	7
STPE	10	2	6	8	4	6	8	4	6	8	4	6	8	4	6	8	4	6	8	4	6	8	2	8	8	2	8	8	2	8	8	2	8	8	2	8
MIED	9	7	3	9	7	3	11	5	4	10	7	4	10	7	5	10	7	3	10	7	2	8	8	3	9	9	3	9	9	4	11	8	4	11	6	4
DEBI	4	5	0	4	5	0	4	5	0	4	5	0	4	5	0	3	6	0	3	5	0	2	5	0	2	5	0	2	4	0	4	2	1	4	3	0
LIND	6	4	0	6	5	0	7	5	0	7	5	0	7	5	0	6	5	0	7	5	0	7	5	0	6	6	0	6	6	0	6	4	1	6	5	0
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KIEV	13	8	5	12	9	4	12	9	4	12	9	4	12	9	4	12	9	4	12	9	4	12	9	4	11	10	4	11	9	5	12	7	6	12	8	5
DOUR	10	6	4	9	7	4	9	7	4	9	7	4	9	7	4	9	7	4	9	7	4	9	7	4	9	7	4	9	6	5	10	5	5	10	5	5
PRUH	13	8	7	11	8	7	11	10	7	11	10	7	12	9	8	12	9	8	12	10	7	12	9	7	11	10	7	10	8	7	11	6	9	12	7	8
LANN	10	5	8	9	6	8	9	6	7	9	6	7	9	6	7	9	6	7	9	6	7	9	6	7	9	6	7	9	5	8	10	4	8	10	4	8
FREI	10	9	6	11	9	6	11	9	5	11	8	6	12	7	6	12	7	6	9	8	5	9	7	5	8	8	4	8	8	4	9	6	4	9	7	4
GARC	4	4	0	4	5	0	4	5	0	4	5	0	5	4	0	5	4	0	5	4	0	5	4	0	5	3	0	5	4	0	6	3	0	6	3	0
BUDA	3	3	0	2	3	0	3	2	0	3	3	0	4	3	0	4	4	0	4	4	0	4	2	0	4	3	0	3	3	0	4	1	1	4	2	0
BEKE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SCHW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
POIT	13	8	7	12	9	7	12	9	7	12	9	7	12	9	7	12	9	7	12	9	7	12	9	7	11	10	7	11	9	8	12	7	9	12	8	8
BEOG	9	7	5	9	7	5	8	8	4	9	8	5	8	8	5	8	8	5	7	8	5	9	8	5	8	9	5	8	8	5	9	6	6	9	7	4
SOFI	11	7	5	10	8	5	10	8	5	9	8	5	10	8	5	10	8	5	10	8	5	10	8	5	9	9	5	9	9	5	10	7	6	10	8	5
ROME	19	11	12	18	12	12	18	13	12	18	12	13	19	11	13	19	11	13	19	12	12	19	12	12	18	13	12	18	12	13	19	10	14	19	11	13
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ELAR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

(a)

M(3000)F2 L: R12 < 60 M: R12 60–110 H: R12 > 110

	JAN			FEB			MAR			APR			MAY			JUN			JUL			AUG			SEP			OCT			NOV			DEC		
	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H
UPPS	12	8	8	11	9	8	11	10	7	11	10	7	11	9	7	11	9	7	11	9	7	10	9	6	10	9	7	10	8	8	11	7	9	11	8	8
SOUT	2	0	2	3	1	2	3	1	2	2	1	2	3	1	2	2	1	2	3	1	2	3	0	2	3	0	2	3	0	2	3	0	2	3	0	2
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JULI	13	7	6	12	8	6	12	8	6	12	8	6	12	8	6	12	8	6	12	8	6	12	8	6	11	9	6	11	8	7	12	6	8	12	7	7
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MIED	7	7	3	8	7	3	9	5	4	8	6	4	8	6	5	8	6	3	9	7	2	7	8	3	8	8	3	8	8	4	10	7	4	10	6	4
DEBI	4	5	0	4	5	0	4	5	0	4	5	0	4	5	0	3	6	0	3	5	0	2	5	0	2	5	0	2	4	0	4	2	1	4	3	0
LIND	6	3	0	7	4	0	7	4	0	7	4	0	7	4	0	7	4	0	7	4	0	7	4	0	6	5	0	6	5	0	7	4	0	6	4	0
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KIEV	13	8	5	12	9	4	12	9	4	12	9	4	12	9	4	12	9	4	12	9	4	12	9	4	11	10	4	11	9	5	12	7	6	12	8	5
DOUR	10	6	4	9	7	4	9	7	4	9	7	4	9	7	4	9	7	4	9	7	4	9	7	4	9	7	4	9	6	5	10	5	5	10	5	5
PRUH	2	0	0	1	1	0	1	1	0	1	1	0	1	1	0	1	1	0	1	1	0	1	0	1	1	0	1	1	0	1	1	0	1	1	0	1
LANN	10	5	8	9	6	8	9	6	7	9	6	7	9	6	7	9	6	7	9	6	7	9	6	7	9	6	7	9	5	8	10	4	8	10	4	8
FREI	10	9	6	11	9	6	11	9	5	11	8	5	12	7	5	12	7	5	9	8	5	9	7	5	8	8	5	8	8	5	9	6	5	9	7	5
GARC	4	4	0	4	5	0	4	5	0	4	5	0	5	4	0	5	4	0	5	4	0	5	4	0	5	3	0	5	4	0	6	3	0	6	3	0
BUDA	3	3	0	2	3	0	3	2	0	3	2	0	4	3	0	4	4	0	4	4	0	4	2	0	4	3	0	3	3	0	4	1	1	4	2	0
BEKE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SCHW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
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ROME	19	11	9	18	12	9	18	12	9	18	11	10	19	10	10	19	10	10	19	11	9	19	11	10	18	12	10	18	12	11	19	10	12	19	11	10
TORT	2	4	0	2	4	0	2	4	0	1	5	0	0	3	0	0	2	0	1	3	0	1	1	0	1	4	0	1	4	0	2	2	0	2	4	0
LISB	1	0	4	1	1	4	1	2	3	1	1	3	1	1	3	1	0	3	1	0	3	1	0	3	1	0	4	1	0	4	1	0	4	1	0	4
ATHE	2	3	0	1	2	0	1	2	0	1	3	0	0	1	0	1	1	0	1	2	0	1	1	0	1	1	0	1	1	0	0	0	0	0	0	0
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ELAR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

(b)

TABLE 2: Number of years of monthly median measurements in PRIME Data Bank (a) foF2 (b) M(3000)F2

foF2 L: R12 < 60 M: R12 60–110 H: R12 > 110

	JAN			FEB			MAR			APR			MAY			JUN			JUL			AUG			SEP			OCT			NOV			DEC		
	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H
UPPS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
SOUT	D	D		D	D		D	D		D	D		D	D		D	D		D	D		D	D		D	D		D	D		D	D		D	D	
KALI	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
JULI	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
STPE	X																																			
MIED	X	X	D	X	X		X	X		X	X		X	X	X	X	X		X	X		X	X		X	X		X	X		X	X		X	X	
DEBI	D	X	D	D	X	D	D	X	D	D	X	D	D	X	D	D	X	D	D	X	D	D	X	D	D	X	D	D	D	D	D	D	D	D	D	D
LIND	X	D	D	X	X	D	X	X	D	X	X	D	X	X	D	X	X	D	X	X	D	X	X	D	X	X	D	X	X	D	X	D	D	X	X	D
SLOU	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
KIEV	X	X	X	X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X	X	X	X	X	X	X	X
DOUR	X	X	D	X	X	D	X	X	D	X	X	D	X	X	D	X	X	D	X	X	D	X	X	D	X	X	D	X	X	X	X	X	X	X	X	X
PRUH	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
LANN	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X		X
FREI	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X		X	X		X	X	
GARC	D	D		D	X		D	X		D	X		X	D		X	D		X	D		X	D		X	D		X	D		X	D		X	D	
BEBU	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
SCHW	D	D		D	D		D	D		D	D		D	D		D	D		D	D		D	D		D	D		D	D		D	D		D	D	
POIT	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
BEOG	X	X	X	X	X	X	X	X	D	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
SOFI	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
ROME	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
TORT	D	X	D	D	X	D	D	X	D	D	X	D	D	D	D	D	D	D	D	D		D	D	D	D	X	D	D	X	D	D	D	D	D	D	D
LISB																																				
ATHE	X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X		
GIBI	X		X			X				X			X			X			X			X			X			X		X	X		X	X		X
ELAR																																				

(a)

M(3000)F2 L: R12 < 60 M: R12 60–110 H: R12 > 110

	JAN			FEB			MAR			APR			MAY			JUN			JUL			AUG			SEP			OCT			NOV			DEC		
	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H
UPPS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
SOUT																																				
KALI	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
JULI	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
STPE	X																																			
MIED	X	X		X	X		X	X		X	X		X	X	X	X	X		X	X		X	X		X	X		X	X		X	X		X	X	
DEBI		X			X			X			X			X			X			X			X			X										
LIND	X			X			X			X			X			X			X			X			X	X		X	X		X			X		
SLOU	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
KIEV	X	X	X	X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X	X	X	X	X	X	X	X
DOUR	X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X	X	X	X	X	X	X	X
PRUH																																				
LANN	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X		X
FREI	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
GARC					X			X			X		X			X			X			X			X			X			X			X		
BEBU																																				
SCHW																																				
POIT	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
BEOG	X	X		X	X		X	X		X	X		X	X		X	X			X		X	X		X	X		X	X		X	X		X	X	
SOFI																																				
ROME	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
TORT											X																									
LISB																																				
ATHE																																				
GIBI	X									X			X			X			X			X			X			X			X			X		
ELAR																																				

(b)

TABLE 3: Cases of 5 or more years of measurements (a) foF2 (b) M(3000)F2

X PRIME Data Bank

D World Data Centre

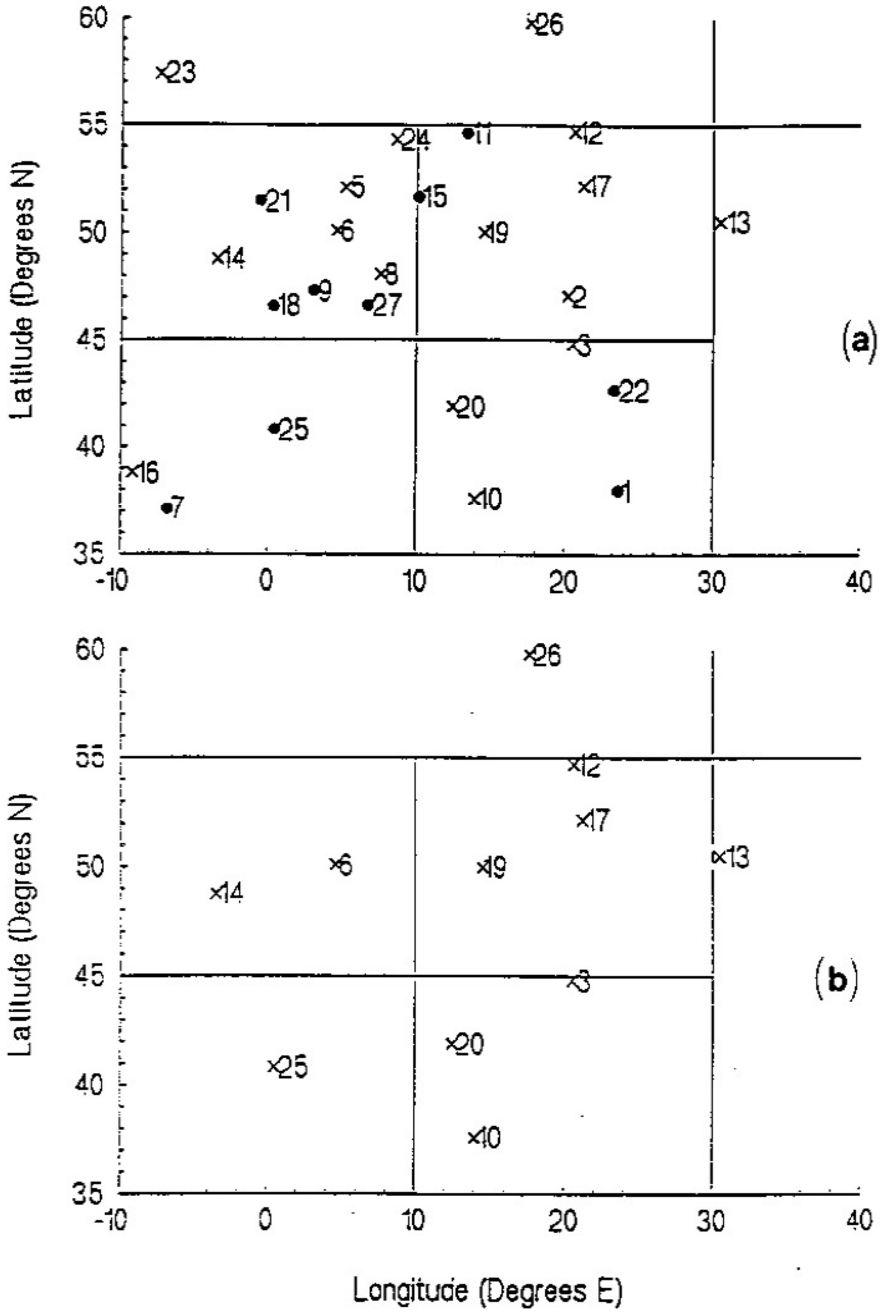

FIG. 1 PRIME area vertical-incidence ionosondes
(a) agreed at Roquetes for map generation and testing
(b) used for NEW mapping
X map generation • map testing

Key	Name	Key	Name
1	Athens	16	Lisbon
2	Bekescsaba/Budapest	17	Miedzeszyn
3	Beograd	18	Poitiers
5	De Bilt	19	Pruhonice
6	Dourbes	20	Rome
7	El Arenosillo	21	Slough
8	Freiburg	22	Sofia
9	Garchy	23	South Uist
10	Gibilmanna	24	St Peter Ording
11	Juliusruh	25	Tortosa
12	Kaliningrad	26	Uppsala
13	Kiev	27	Schwarzenburg
14	Lannion		
15	Lindau		

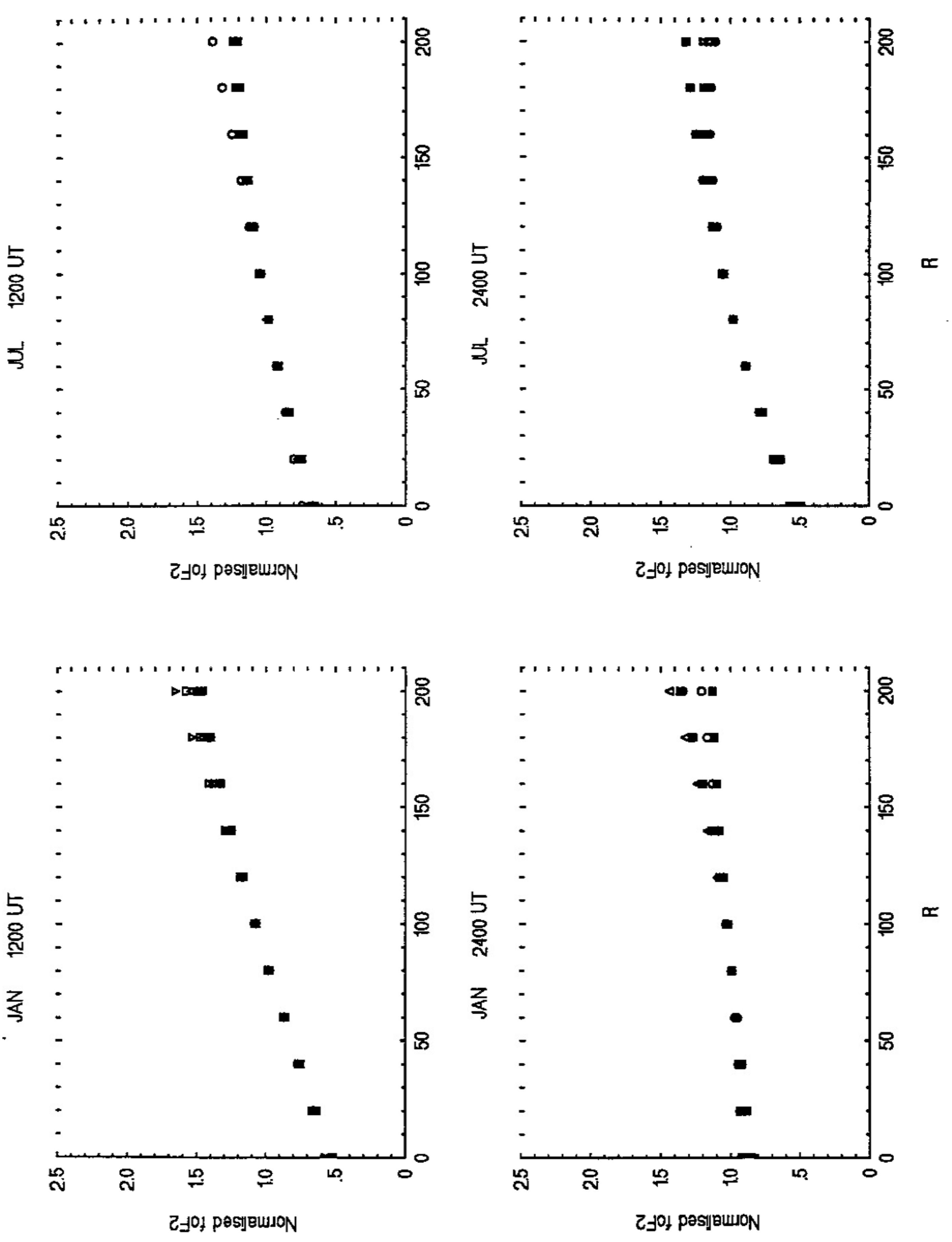

FIG. 2 foF2 versus R for selected hours and months for the 6 stations Slough, Rome, Poitiers, Lannion, Dourbes and Beograd (from data analyses of Kouris). Values are shown expressed as a fraction of figures for R=85.

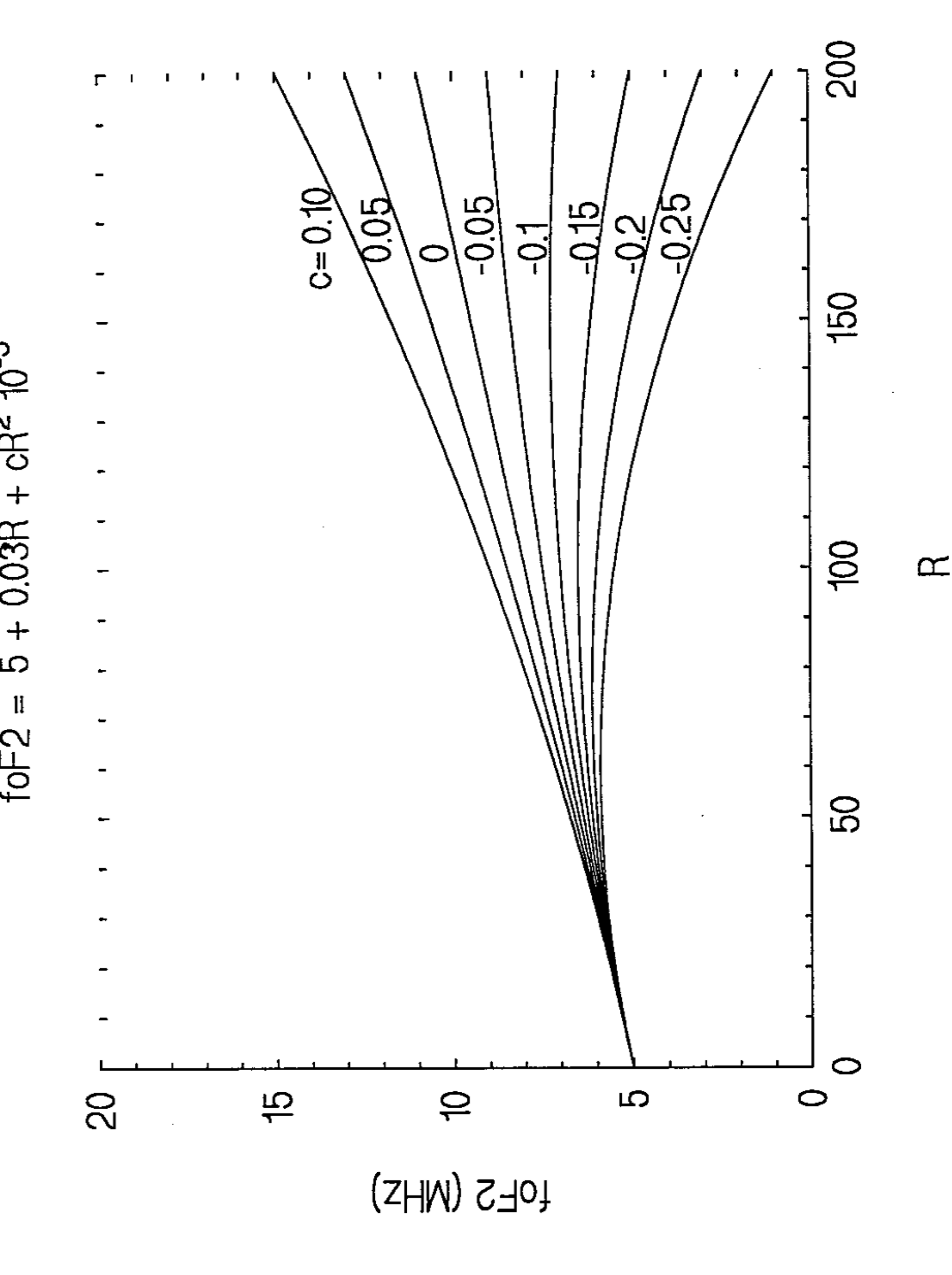

FIG. 3 Variation of foF2 with R for different c in winter noon.

FIG. 3 Variation of foF2 with R for different

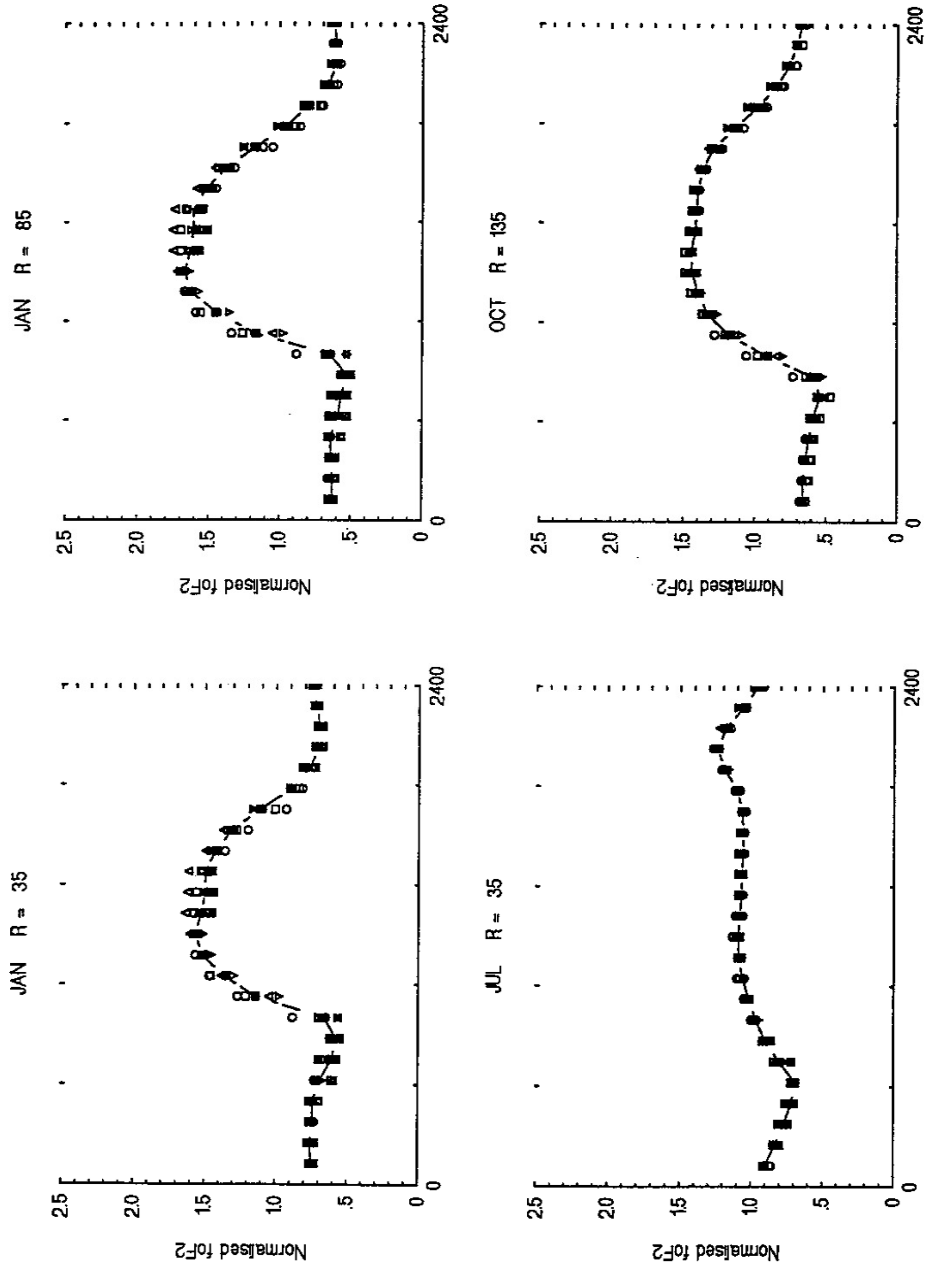

FIG. 4 Normalised diurnal variations of foF2 for 6 stations of Fig. 2 for sample months and R as indicated.

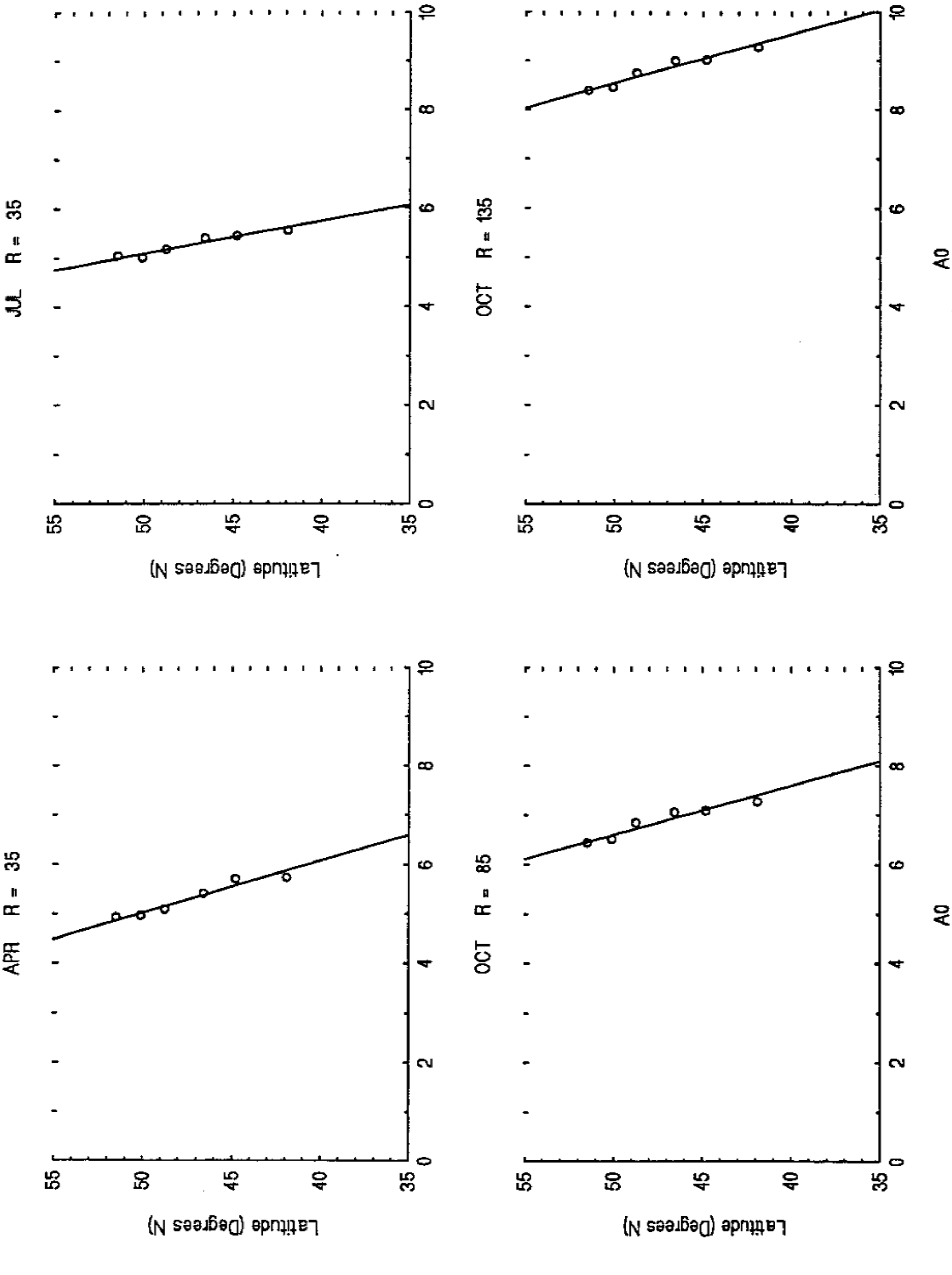

FIG. 5 Latitude variation of 24-hour mean foF2 amplitude normalisation factor A0 for sample months and R as indicated.

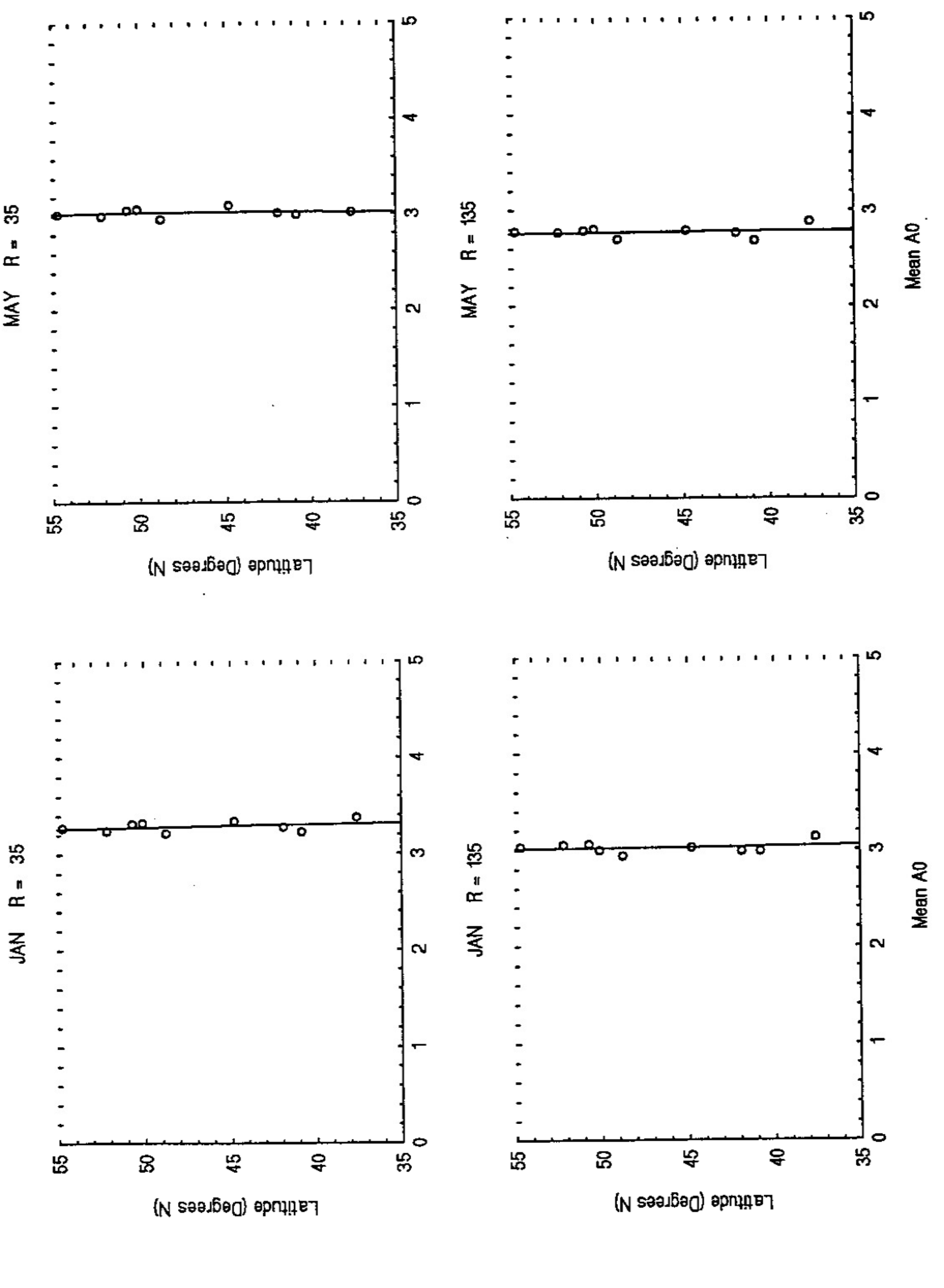

FIG. 6 Latitude variation of 24-hour mean M(3000)F2 amplitude normalisation factor A0 for sample months and R as indicated.