COST 238/PRIME WORKSHOP

on "Development an Testing of an electron density height profile model for PRIME"

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OVERVIEW

COST (Cooperation in Scientific and Technological Research) is an initiative of the European Union providing a framework whereby researchers in the different Member States can work together to mutual advantage on common problems, thereby helping to build up an improved Community technological base to better support industry. COST covers a range of disciplines, one of which is Telecommunications, and consists of a number of separate Projects (Actions) each with defined objectives and lifetimes.

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.

With separate teams formed from within the different organisations on a topic-by-topic basis, work has progressed by correspondence stimulated by periodic Workshops at which papers have been presented to the full group. With adequate planned times for discussion Workshops have proved valuable fora for the formulation of plans for the ways ahead.

The 7th Workshop in the series with some 40 participants was held at El Arenosillo, Mazagon, Spain on 5-6 September 1994 followed by a three day management meeting. The Workshop theme was the 'Development and testing of an electron-density height profile model for PRIME'. In total 19 papers were presented, also covering other topics in the fields of vertical and oblique sounding, instantaneous and long-term mapping and short-term predictions. Additionally there were some 10 poster papers. This last Workshop to be organised under project auspices can indeed be regarded as most successful. Besides paving the way for specification of a height profile model of electron density (with a specialised group commissioned to meet subsequently in Florence, Italy in October 1994 to finalise this) most important decisions were taken on the methods of long-term and instantaneous mappings to adopt. I am grateful to the Working Group Leaders for their help in formulating the Workshop programme.

This Proceedings contains a selection of Workshop papers. In addition, 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 grateful to Dr Benito A de la Morena from the Centro de Experimentacion de El Arenosillo of the Instituto Nacional de Técnica Aeroespacial for hosting us. We extend our sincere thanks to him and his colleagues for all they did to ensure the event was a success. We especially thank Colonel Juan Jose Martin Francia, Director of the El Arenosillo facility, for allowing the meeting to take place and INTA, provincial and local governments for their hospitality.

Sadly this was the last occasion on which everyone was present together. It was indeed a fitting and very memorable way to end.

Finally our thanks go to Benito for preparing this publication.

Peter A Bradley
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KIMS - a new method of instantaneous mapping using screen-point values in remote areas

by

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Introduction

Various previous studies [1, 2] have considered the respective merits of different computer contouring approaches to the gridding of data for instantaneous ionospheric mapping and have led to the conclusion that Kriging provides most accurate results of those methods considered.

The basis of Kriging is to apply weighted interpolation among adjacent data points where the weighting factors are proportional to the semivariance between values. In effect as an intermediate stage a semivariogram is computed giving the dependence of the semivariance on distance separation. In order to formulate the semivariance data points are used with separations in all directions - that is to say, the semivariance is assumed to be isotropic. Yet it is known that the correlation distance of change in the undisturbed ionosphere (over which the correlation coefficient falls to a value of ε^{-1}) is typically 500 km in a N-S direction and 1000 km in an E-W direction. Hence a 2:1 latitude coordinate scaling factor has been applied to all data prior to gridding to take account of this difference in correlation distances and it has been convincingly demonstrated, confirmed also in parallel collaborative tests with Polish colleagues using their own generated version of the Kriging procedure, that gridding errors are thereby reduced [3]. Simulated data comparisons [3] have also shown error reductions when, as theory predicts, mean drift is eliminated prior to gridding.

Taking account of these features a package basic Kriging procedure KIM (Kriging method of instantaneous mapping) is proposed incorporating the following features:

- rectangular gridding on a 5° latitude and 10° longitude separation

- values given by weighted interpolation, where the weighting factors are proportional to the semivariance

- the semivariogram being taken as an exponential function approximation to the measured semivariances

- application of a factor of two latitude coordinate scaling, and

- elimination of mean latitude drift prior to gridding

Other work by the present group [4] and also by other PRIME participants has investigated the use of single-station models and the merits of generating synthetic input data values in remote areas, so as to constrain results to physically realistic figures, rather than to let these be determined by mathematical expressions. Available options for specifying the locations of so-called 'screen points' and the values to adopt for each of these have been addressed [4]. A specific procedure (KIMS) has been formulated (Kriging method of instantaneous mapping with screen points). Details are given over.

Locations of screen points

Screen points are taken on a rectangular latitude-longitude grid every 5° of latitude and every 10° of longitude, but excluding all screen points closer than 5° of latitude and 10° of longitude from a measurement location. Figure 1 illustrates the situation.

Screen-point values

Three separate cases are considered for the determination of the screen-point values, depending whether measurements exist within the surrounding 5° latitude/10° longitude area for the same hour on the immediately previous 3 days, or on the same day at previous hours from which the diurnal trend can be deduced. If there are no such measurements then long-term predicted values are adopted using effective sunspot numbers chosen to minimise the mean prediction error over all available measurement locations.

In the first case we look to see if any measured values are available for one or more locations within 5° latitude/10° longitude of the screen point on any of the previous 3 days at the hour in question. For each such location with measurements on all three days, values are combined and the median taken. This way we try to formulate a best estimate of likely conditions for the day in question without bias by data values which are not representative of several days, allowing for the fact that day-to-day variability can be significant. This approach is consistent with known findings of Rush who has shown that combining several recent past days results without weighting is better than taking a monthly median or just the value for the last day.

When the above condition is not met but measured values are available for one or more locations within 5° latitude/10° longitude of a screen point for the same day at the previous hour and for 5 or more of 9 possible epochs one hour before, the same hour and one hour after on the previous 3 days then these data are combined and the diurnal trend determined by parabolic regression through these earlier days of data. The resulting relationship is then applied to extrapolate from the previous hour value for the day in question.

If no suitable measurement data exist as indicated above then screen-point values are determined using the long-term prediction method LINLAT developed within the NEW initiative [5] - see Annex with appropriate effective sunspot numbers as noted above.

Conclusions

Instantaneous mapping procedures KIM and KIMS are offered for coding and accuracy evaluation in accordance with agreed assessment procedures.

References

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4. P A Bradley, M I Dick and Lj R Cander, 'Single-station locations and model formats for screen point values specification in instantaneous mapping', Proceedings of the COST 238 Workshop on 'Numerical mapping and modelling and their applications to PRIME', Eindhoven, May 1994, pp 61-64.

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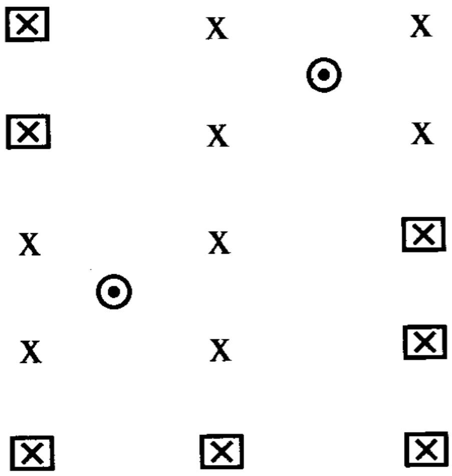

Fig 1 Example of screen-point location determination

x grid points

⊙ measurement locations

☒ screen points

ANNEX

Specification of LINLAT (NEW-5)
(common diurnal variation)

Computer program LINLAT (NEW-5) provides estimates of monthly median foF2 and M(3000)F2 within the PRIME area as functions of geographic latitude λ (degrees N of the Equator), longitude θ (degrees E of Greenwich), Universal Time T (hours), month (January = 1 through December = 12) and 12-monthly smoothed sunspot number R. It is based on empirical relations fitted to a multi-station data set of measured values common to all the NEW mappings. This assumes a parabolic dependence of foF2 on R given in terms of the values Ω_1 - Ω_3 for R = 35, 85 and 135 respectively and assumes a linear dependence of M(3000)F2 on R given in terms of the values Ω_4 and Ω_5 for R = 35 and 135 respectively.

So we have that

$$\text{foF2}(\lambda, \theta, T, M, R) = a(\lambda, \theta, T, M) + b(\lambda, \theta, T, M)R + c(\lambda, \theta, T, M)R^2$$

and $$\text{M(3000)F2}(\lambda, \theta, T, M, R) = d(\lambda, \theta, T, M) - e(\lambda, \theta, T, M)R$$

with $$a = 2.295\Omega_1 - 1.890\Omega_2 + 0.595\Omega_3$$

$$b = -0.044\Omega_1 + 0.068\Omega_2 - 0.024\Omega_3$$

$$c = 0.0002\Omega_1 - 0.0004\Omega_2 + 0.0002\Omega_3$$

$$d = 1.35\Omega_4 - 0.35\Omega_5$$

$$e = 0.01(\Omega_4 - \Omega_5)$$

The basis of LINLAT is that for a given month and R then foF2 and M(3000)F2 expressed in local time and normalised by the 24-hour mean value is independent of location. So these ionospheric characteristics can each be specified in terms of 24 separate hourly values. Furthermore, in the case of foF2 the normalisation constant is a linear function of geographic latitude and has no discernible longitude dependence; with M(3000)F2 it is totally independent of location.

For foF2 we define arrays LINLAT F2 [24, 12, 3] containing the 24 integer local time omega values for each of the twelve months and each of the three Ω terms for λ = 35° and LINLAT SL [12, 5] as the latitude gradient change satisfying:

$$\Omega = \text{LINLAT F2}\,[1 + \text{LINLATSL}\,(\lambda - 35)]$$

For M(3000)F2 array LINLATM3 [24, 12, 2] contains the 24 integer local time omega values for each of the twelve months satisfying Ω = LINLATM3

So the complete mapping requires 24 x 12 x 5 + 12 x 3 = 1476 coefficients.

For Universal Time T (hours) the local time L is: $L = T + \frac{\theta}{15}$, and the corresponding foF2 and M(3000)F2 are given by appropriate interpolation among the values determined as above.