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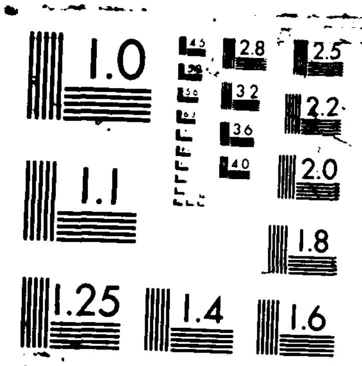
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DERIVATION OF CONSISTENT SURFACE FIXED FIELDS FOR USE IN A GLOBAL NWP MODEL

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In this report we describe a method for generating a consistent set of surface fixed fields for use in a global NWP model. These fields include orography, the land sea mask and the sea surface temperature. The method is based on two principles. First, the interpolation from the higer resolution data grid to the coarser resolution model grid is done with a local filtering or analysis technique. Second, the three analyzed fields are kept consistent by using the same method and filter parameters for each field. The basic orographic data set is the 1 X 1 degree Sripps data. This is used to produce the model grid values of orography and the land sea mask. The basic data for the sea surface temperature consists of monthly mean values on the 2.5 X 2.5 degree grid used by NMC. For the orography and land sea mask, we first use the basic data to generate values on the 2.5 X 2.5 degree grid. Then all three fields are interpolated to the model grid. The resulting land sea mask also allows for fractional land coverage at model grid points.
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1. INTRODUCTION

In this report, we describe the procedure that we have developed for deriving consistent surface fixed fields for a global numerical forecast model. While the model we are using is the Air Force Geophysics Laboratory (AFGL) global spectral model (Brenner et al., 1982 and 1984), the procedure and resulting surface fields decribed are in fact applicable to any global model. By the term surface fixed fields, we refer specifically to the three fields that are needed in a model to describe the surface of the earth, i.e. the orography, the sea surface temperature and the land sea mask. The first two fields are needed for the computation of the various boundary forcing terms in the model. The land sea mask is used as a flag to determine if a particular grid point is to be treated as land, sea or a combination of both for the purposes of surface flux computations.

In the baseline version of the AFGL model, surface fluxes of momentum, sensible heat and moisture are computed according to bulk aerodynamic formulae (Brenner et al., 1982). Surface drag (i.e. momentum flux) is computed at all grid points while sensible heat and moisture fluxes are only computed over ice free ocean points. The land sea mask is a simple yes/no flag so that any given model grid point is treated as either all land or all sea. Furthermore, this flag is derived from the sea surface temperature field. As a result of this uncoupling between the orography and the land sea mask, many coastal grid points are treated as ocean for the purposes of surface flux calculations yet the surface height at these points can be substantially greater than zero. It is precisely this inconsistency that we wish to eliminate through use of the interpolation procedure that will be described below. Our second goal in deriving consistent surface fixed fields is to allow for partial land coverage at model grid points and thereby improve the simulation of surface fluxes at coastal points.

Finally, we note that a fourth field which is also associated with the surface of the earth is the neutral drag coefficient. We do not explicitly discuss it in this report since its specification varies widely among the many global models that are in use today. Our treatment of the drag coefficients and the surface fluxes will be the subject of a separate report.

2. SURFACE FIXED FIELDS

As mentioned above, the lower boundary conditions for the model require the specification of the orography, the land sea mask and the sea surface temperature. The final model grid point values used must in some sense represent grid box averages. However it is not at all obvious what the most appropriate method is to average or interpolate the "observed" values (presumably available on a high resolution grid) on to the coarser resolution model grid. The possibilities include methods such as linear interpolation, local filtering (e.g. Gordon and Stern, 1982; Pitcher et al., 1983) or area weighting (e.g. Hansen et al., 1983). We note however that in many models, different methods are used for each of the three surface fields. In designing our procedure, we have decided to follow two general principles. First, we use the local filtering method which closely resembles a one pass Cressman (1959) type successive corrections objective analysis scheme. Second, to the extent possible, we try to keep all three surface fields consistent (i.e. use the same interpolation method and parameters).

As the starting point for the interpolation, we will use "observed" data consisting of the surface fields that are available on the 2.5 X 2.5 degree latitude longitude analysis grid used by the National Meteorological Center (NMC). Henceforth, we will refer to this grid as the data grid as distinguished from the model grid on to which we wish to interpolate. The general procedure for interpolating from the data grid to the model grid can be described as follows. The analyzed or filtered field on the model grid is given by

$$F(i) = \sum_{n=1}^{N} D(n)*W(n) \Big/ \sum_{n=1}^{N} W(n) \qquad (1)$$

where F(i) is the filtered or analyzed value at the i-th model grid point, D(n) is the data value at the n-th data point, W(n) is the weighting function, and N is the total number of data points that are allowed to influence the analyzed value. We use a Gaussian weighting function defined by

$$W(n) = \exp\left(-K(r/R)^2\right) \qquad (2)$$

where r is the distance between the data point and the analysis point, R is the radius of influence and K is a parameter that determines the shape of the weighting function. For R we use a value of 1.25 times the grid size of the data grid. This value ensures that at least five data points will be used for each analysis point. For K we use a value of 4.5 which means that 99% of the influence of the N data points is taken into account (Levitus, 1982). In the next three subsections we give the specific details of the analysis procedure for each of the three surface fixed fields. The orography and the land sea mask are derived together and require a two step analysis procedure while the sea surface temperature requires only a single step.

2.1 Orography

Two data sets are available to produce the model orography. One set consists of the surface height values provided on FGGE tapes on the 2.5 X 2.5 degree grid. The alternative set consists of 1 X 1 degree values produced by Scripps Institute of Oceanography and available from NCAR. We have chosen to use the second set since it clearly contains more information on the variance of the orography. Since our interpolation procedure was designed based on the 2.5 X 2.5 degree data grid, two steps are necessary to generate the model orography which will be consistent with the other surface fields. First we use the 1 X 1 degree data to generate values on the 2.5 X 2.5 degree grid and then we interpolate these latter values on to the model grid along with the other surface fields.

In using the 1 X 1 degree data to generate 2.5 X 2.5 degree data we follow the same analysis procedure as outlined above in equations (1) and (2). The only difference is that here the input data consists of the 1 X 1 degree values while the output grid is now the 2.5 X 2.5 degree grid. Once the 2.5 X 2.5 degree data is ready, we can then produce the model grid data exactly as described in the preceeding section. This two step procedure may be somewhat less desirable than interpolating the 1 X 1 degree data directly on to the model grid. However, we must follow this procedure if we wish to take advantage of the information contained in the 1 X 1 degree data and at the same time have consistent surface fields since the sea surface temperature is available only on the 2.5 X 2.5 degree grid.

In Figure 1 we show the orography produced by our method for a model grid consisting of 40 Gaussian latitudes (approximately 4.4 degree spacing) and 48 equally spaced longitudes (7.5 degrees) which is the transform grid for a spectral model with a rhomboidal truncation at wavenumber 15. Note however that the orography shown has not yet been spectrally truncated. Each number on the map represents a range of 500 m according to: blank < 500, 1= 500-999, 2= 1000-1499,..., 9 > 4500 and + at the location of the maximum elevation. All of the major mountain ranges are apparent including the Himilayas, the Rockies, the Andes and the highlands of Antarctica.

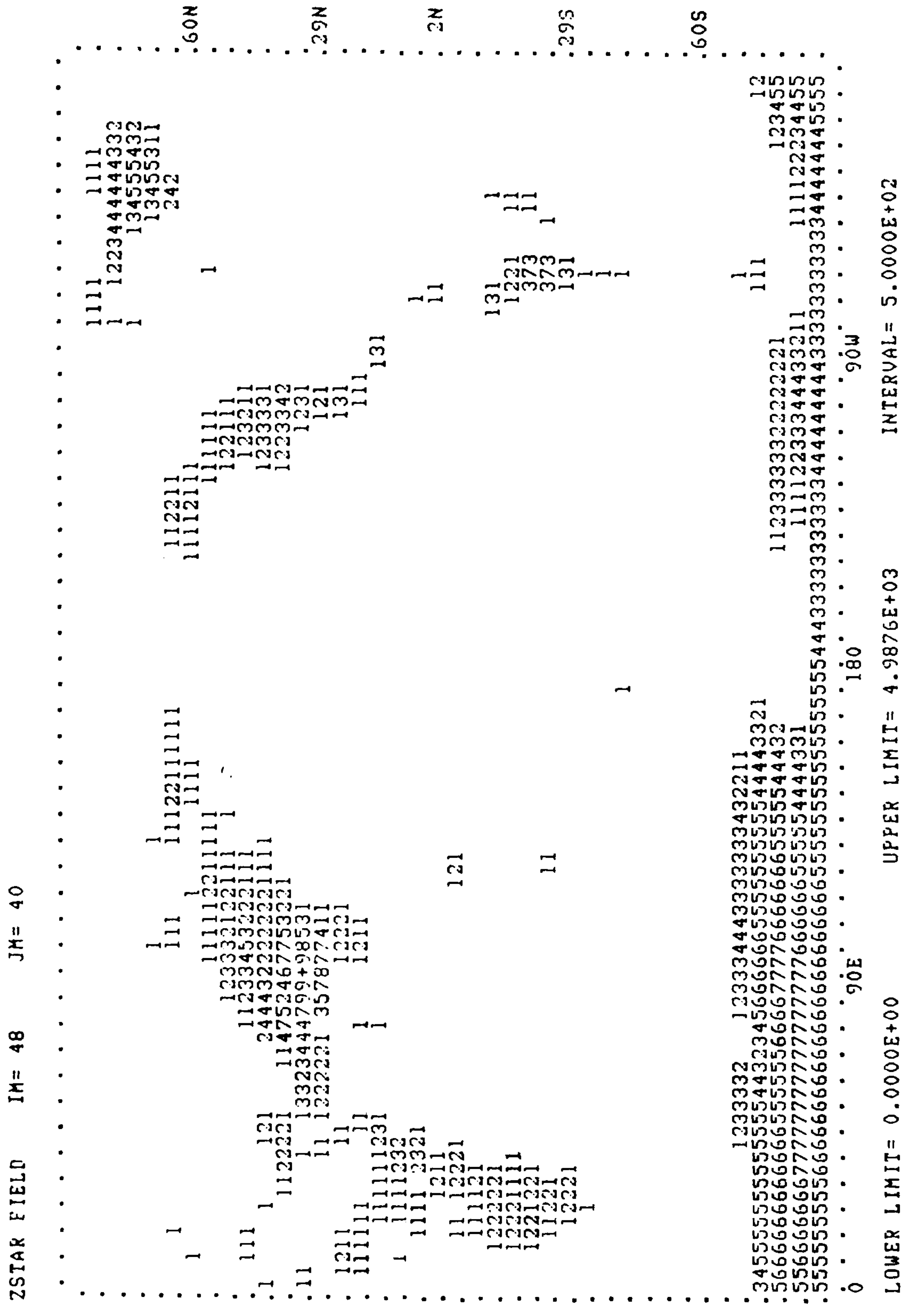

Figure 1: New orography on the 40 X 48 Gaussian grid. Values are as follows - blank < 500 m, 1=501-999, 2=1000-1999,..., 9 > 4500.

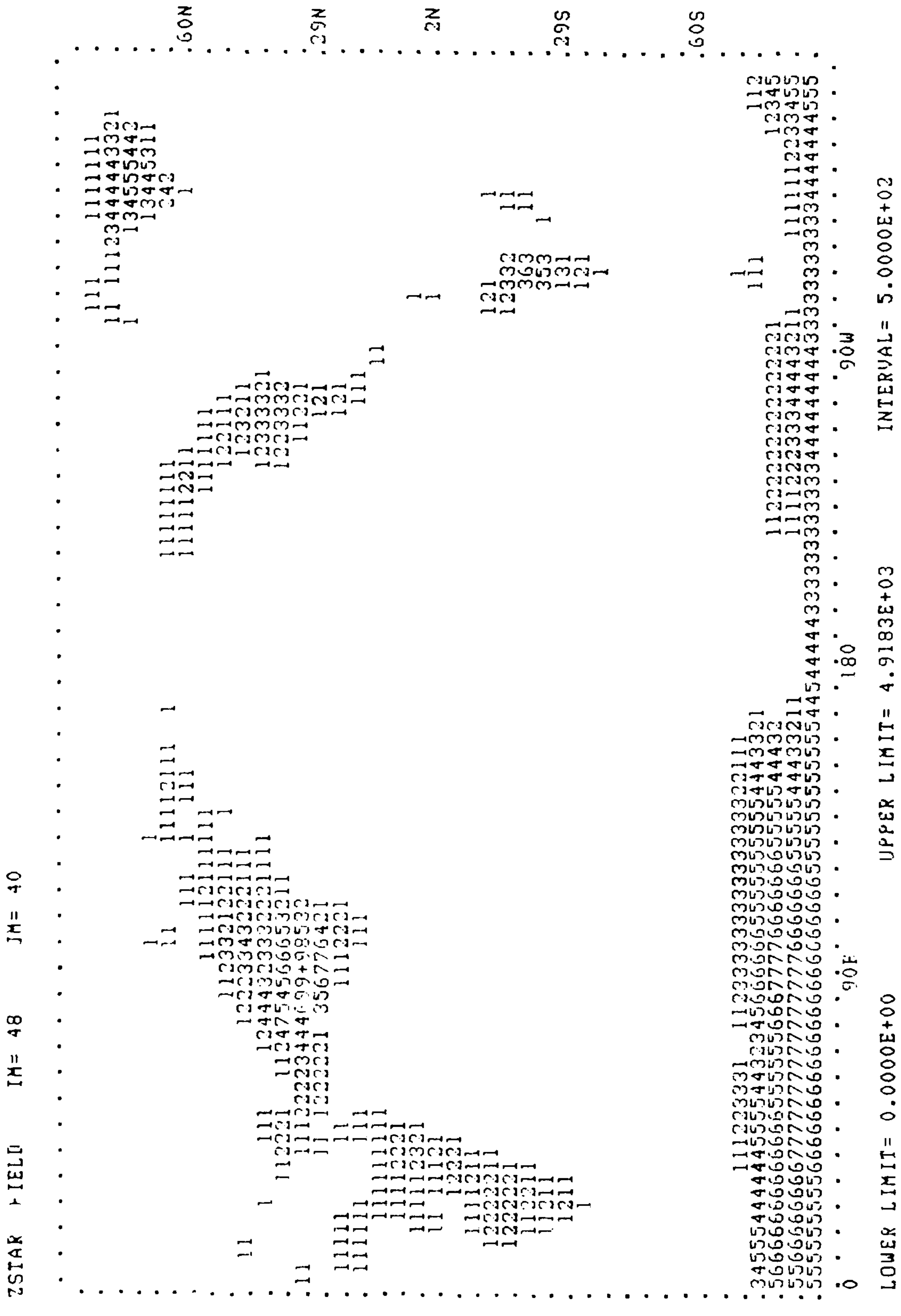

Figure 2: As in Figure 1 except for the smoothed AFGL orography.

For comparison, in Figure 2 we show the smoothed orography that is currently being used in the AFGL model (Brenner et al. 1984). This field was produced by smoothing the 2.5 X 2.5 degree orography twice with a nine point smoother. The smoothed field was then linearly interpolated on to the 40 X 48 point Gaussian grid. The field shown here is also before spectral truncation. Once again, we can see that all of the major mountain ranges are present. Also, from both figures we can see that the maximum elevation values are within 70 m of each other. The most obvious difference between the two figures is the somewhat smoother appearance of Figure 2. This is especially noticeable around the points with the highest elevations. The other major difference between the two orography fields is the question of consistency with the land sea mask and the sea surface temperature field. This issue will be addressed in the next two subsections.

2.2 Land sea mask

The land sea mask is not an observed or measured field. It is simply a flag that is used to indicate which type of surface (land or ocean) is to be used in the computation of the surface fluxes. In many models including the AFGL baseline model the land sea mask is a simple yes/no flag so that any given model grid point will be treated as either all land or all sea. However, given the high resolution 1 X 1 degree topography we can define a land sea mask which will be consistent with the orography and at the same time allow for the possibility of partial land coverage in a grid box.

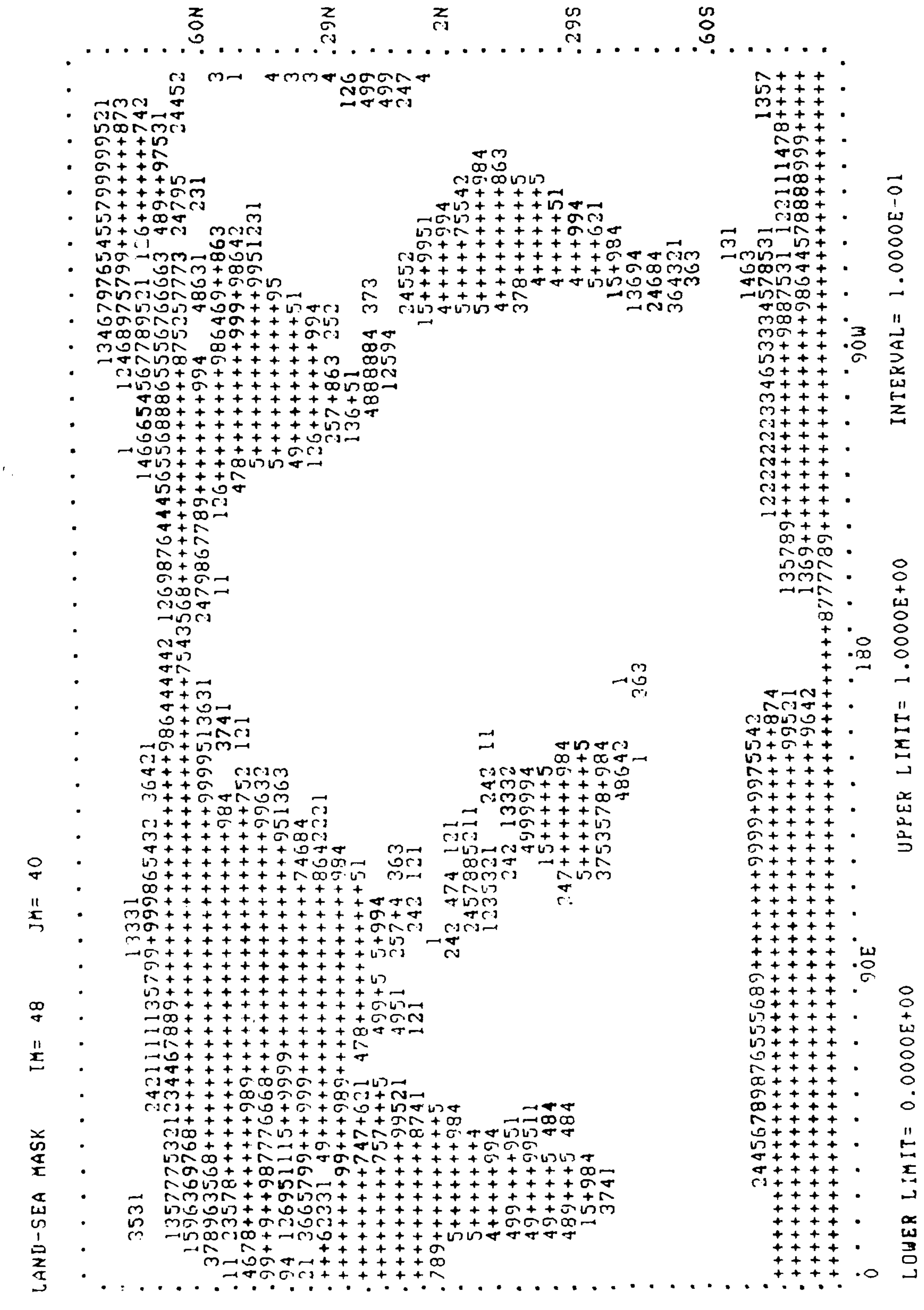

Figure 3: Land sea mask corresponding to orography shown in Figure 1. Values are - blank < 10%, 1=10-19,..., 9=90-98, + > 98% land coverage.

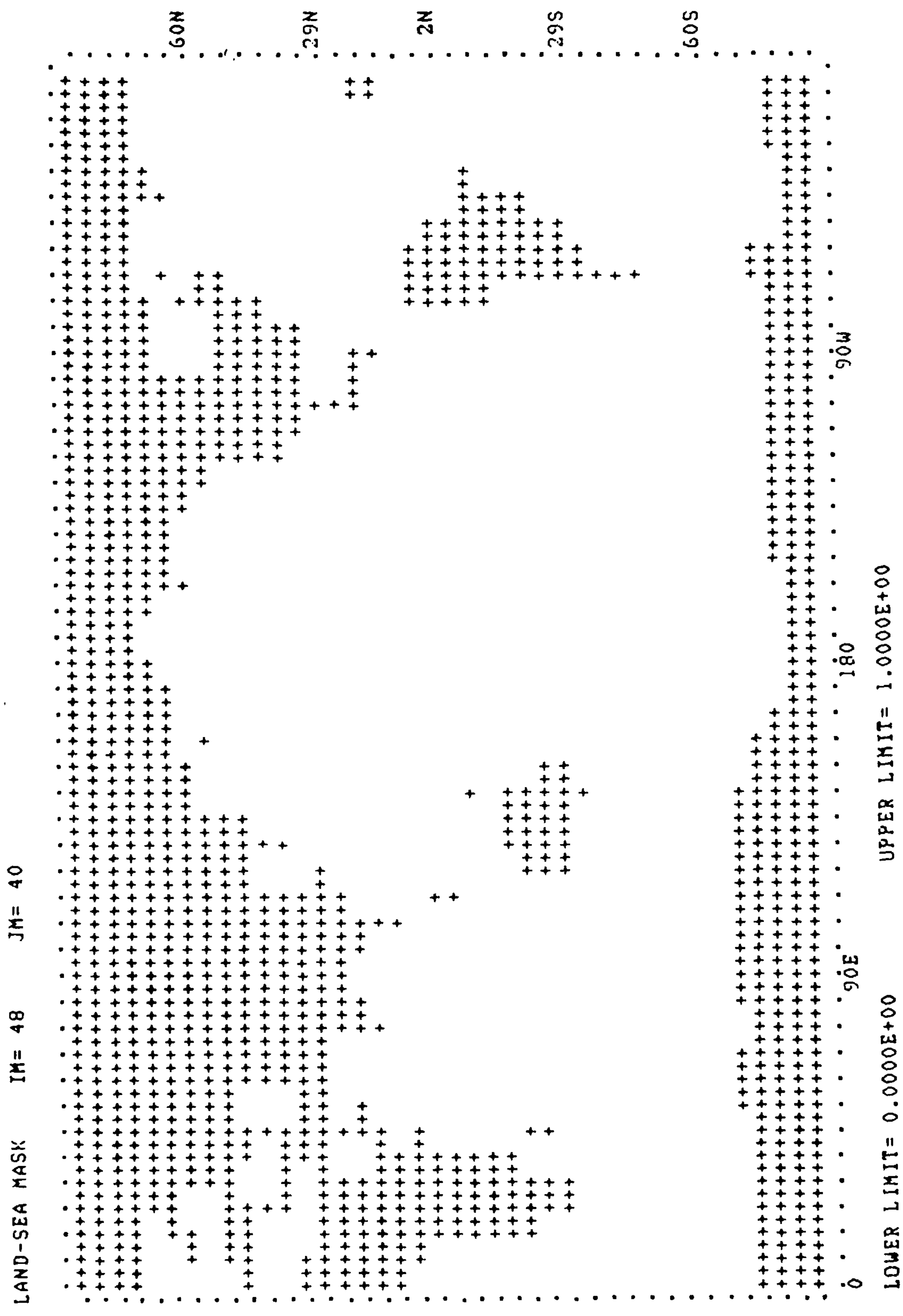

Figure 4: Land sea mask based on sea surface temperature field. A blank is exactly zero while + is exactly 100% land coverage.

The procedure we use here to generate a consistent land sea mask follows directly from the analysis procedure described above for the orography. We begin with the 1 X 1 degree orography data and define the corresponding land sea mask as a yes/no flag so that if the the surface elevation is exactly zero then the grid point is assumed to be all sea (mask=0) while if the elevation is different from zero the point is all land (mask=1). Thus our scheme contains the implicit assumption that the model resolution will never exceed one degree. This 1 X 1 degree land sea mask is then analyzed to give the values on the 2.5 X 2.5 degree grid. At this point, we now have the 2.5 X 2.5 orography and the accompanying land sea mask which consists of values of fractional land coverage at each grid point. The procedure is then completed by analyzing the 2.5 X 2.5 degree fields to give the desired model grid point values.

In Figure 3 we show the land sea mask on the 40 X 48 point Gaussian grid that is consistent with the orography shown in Figure 1. The values shown are the fractional land coverage at each grid point according to: blank < 10%, 1=10-19,..., 9=90-98 and + > 98%. The outlines of all major land masses are clearly reflected by this land sea mask. In Figure 4 we show the land sea mask that is currently used in the AFGL baseline model. This field is a simple yes/no flag set according to the value of the sea surface temperature. In this figure, a blank is exactly zero and a plus is exactly 100%. As might be expected, the continental interiors are the same in both figures. The main differences between the two masks appear in coastal regions and at grid points covered by sea ice. It is precisely here that the question of consistency arises. In the AFGL system (Figures 2 and 4) there are 420 points that are treated as ice free ocean for the computation of surface fluxes of sensible heat and moisture yet the surface elevation at these points is greater than zero. Of these 420 points, 101 have elevations above 100 m, 47 are above 200 m and 9 are above 500 m. In our method of defining surface fixed fields (Figure 1 and 3) this incosistency is completely removed since grid points are allowed to have partial land coverage.

As for sea ice points, it is obvious from Figure 3 that the method used in the AFGL baseline model cannot distinguish between land and sea ice points since the same ficticious temperature is used to flag both types of points in the 2.5 X 2.5 degree FGGE sea surface temperature fields. However, this is not a major difficulty in the baseline model since surface fluxes of sensible heat and moisture are computed only at ice free ocean points.

Finally, we note that the procedure describe above applies to the model grid point values. The surface elevation is used to compute the geopotential and therefore in a spectral model the orography is formally a spectrally truncated field while the land sea mask and the surface fluxes are not. Upon synthesizing the spectrally truncated orography, one will inevitatbly find nonzero values of surface elevation at grid points that are flagged as 100% ocean. Most notably, there will be "holes" in the oceans as a result of spectrally truncating a rough field such as surface elevation. An assessment of this problem is beyond the scope of this work. We note however that no one has yet established the "ideal" method for incorporating orography in a spectral model.

2.3 Sea surface temperature

In producing the surface fixed fields for the model, the sea surface temperature poses the severest restriction since the "observed" data for input to our analysis scheme consists of the 2.5 X 2.5 degree FGGE values. There was no higher resolution data set available for this purpose. It is for this reason that the analysis procedure described in section 2 was designed for interpolating from the 2.5 X 2.5 degree grid to the desired model grid. Thus application of the analysis scheme to the sea surface temperature is straighforward. The only point to note here is that land and sea ice are flagged in the data by assigning a ficticiously low value of temperature. If such a data grid point is encountered by the analysis then the weight of that data point is set to zero and it is therefore not allowed to influence the analyzed value.

3. SUMMARY

In this report we have described a method for generating a consistent set of surface fields (orography, land sea mask and sea surface temperature) for use in a global model. In designing this procedure, we were guided by two basic principles. First, we use a local filtering or analysis technique which is essentially a one pass Cressman (1959) objective analysis scheme. Second, to the extent possible, we have tried to maintain consistency by using the same procedure and filter parameters for all three fields. The orography and land sea mask require a two step procedure since we wish to take advantage of the availablility of the 1 X 1 degree orography data. From this basic data we generate the 2.5 X 2.5 degree values of orography and land sea mask. These two fields along with the 2.5 X 2.5 degree FGGE sea surface temperature are then interpolated on to the desired model grid according to the analysis scheme described in section 2. The resulting fields allow for the use of fractional land coverage in the computation of the surface fluxes of momentum, sensible heat and moisture.

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