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[The Hemispheric Eighth Mesh Terrain Elevation and Geography Data Sets

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13. ABSTRACT *(Maximum 200 words)*

A number of meteorological models at the Air Force Global Weather Central (AFGWC) make use of eighth mesh resolution terrain elevation and geography (land/coastline/water) data sets. Unfortunately, the data sets currently in use at AFGWC are of extremely poor quality. Therefore, as part of GL efforts to upgrade the Real-Time Nephanalysis Model, new hemispheric eighth mesh (approximately 25 nautical mile resolution) data sets were developed. The global Navy 10 arc minute terrain elevation and land characteristics data (approximately 10 nautical mile resolution) were used as source data. This report describes the averaging and remapping techniques used in the development of these new accurate hemispheric data sets.

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The Hemispheric Eighth Mesh Terrain Elevation and Geography Data Sets

1. BACKGROUND

Fundamental to most applications in remote sensing or modeling of the atmosphere is a firm understanding of the characteristics of the earth's surface. Global determination of parameters that vary on daily or seasonal scales (such as skin temperatures, snow cover, soil characteristics, or vegetation types) is usually difficult to obtain and verify. Accurate determination of topography however, exists for most of the earth's surface. Therefore, the use of erroneous terrain elevation data introduces unnecessary inaccuracies into atmospheric models and retrieval techniques.

A number of models at the Air Force Global Weather Central make use of eighth mesh terrain and geography (land/coastline/water) data sets. These models include the Real-Time Nephanalysis (RTNEPH), the Surface Temperature Model, the Improved Point Analysis Model (IPAM) and the Agromet Program. Unfortunately, it has long been recognized that the AFGWC eighth mesh terrain data (particularly in the Southern Hemisphere) were of extremely poor quality (see Figures 1a, 2a, and 3a). Therefore, as part of on-going efforts to upgrade the Satellite Processor of the RTNEPH, new eighth mesh terrain data sets were developed at the Geophysics Laboratory (GL). Since eighth mesh data correspond to a fairly coarse resolution of

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approximately 25 nautical miles (NM), the higher resolution global Navy 10 arc minute terrain and land characteristics data (approximately 10 NM resolution) were chosen as the source data in this effort. The following report describes the averaging and remapping techniques used in the development of these new accurate eighth mesh hemispheric terrain and geography data sets.

2. DATA SOURCES

The hemispheric mesh grid system used at AFGWC is based on secant polar stereographic projections true at 60° N and S (Hoke *et al.*, 1981). The projection is divided into a rectangular whole mesh grid with the grid points on the earth's surface 381 km apart at 60° N and S. Each whole mesh box can then be further subdivided into half mesh (2×2), eighth mesh (8×8), sixty-fourth mesh (64×64), etc. The latitude ϕ of any grid point can be determined by

$$\phi = H \sin^{-1} \left\{ \frac{\left(\frac{a}{d_0 M}\right)^2 (1 + H \sin\phi_0)^2 - (X^2 + Y^2)}{\left(\frac{a}{d_0 M}\right)^2 (1 + H \sin\phi_0)^2 + (X^2 + Y^2)} \right\},$$

and the longitude λ of any grid point by

$$\lambda = \begin{cases} \lambda_0 + \cos^{-1}\left(\frac{X}{(X^2 + Y^2)^{1/2}}\right), & Y \geq 0, \\ \lambda_0 - \cos^{-1}\left(\frac{X}{(X^2 + Y^2)^{1/2}}\right), & Y \leq 0, \end{cases}$$

where H is a hemispheric flag with a value of +1 for the Northern Hemisphere and -1 for the Southern, a is the earth's radius (6371.2213 km), M is the mesh factor, d_o is the distance between whole mesh boxes (381 km) at the reference latitude of ϕ_o (which is 60°), X and Y are the Cartesian coordinates (i,j) of a gridpoint, and the reference longitude λ_o is 10° E. The corners of the grid are off-hemisphere and are not filled with data. There are a total of 512×512 eighth mesh boxes on each hemispheric grid.

2.1 Original AFGWC Terrain Data

The original AFGWC eighth mesh terrain data set was prepared with interpolated values from the 1 degree latitude and longitude global terrain data set from Scripps Institution of Oceanography (circa 1965). Selected areas were subsequently upgraded by the introduction of subjectively averaged elevation values taken from DOD Operational Navigation Charts (Fye, 1978). Unfortunately, the interpolation scheme initially used introduced spurious grid patterns into the data (especially in the Southern Hemisphere). The boundaries between the original interpolated fields and subsequent upgraded areas are clearly evident, creating sharp discontinuities in the data. Ideally, given that the nominal resolution of eighth mesh is 25 NM, a finer resolution data source should have been used rather than a coarser one. Fortunately for the development of the GL eighth mesh project, a global 10 arc minute terrain data set has been prepared at the Naval Fleet Numerical Oceanographic Center (NFNOC) and is distributed to the scientific community by the National Center for Atmospheric Research (NCAR) and by the National Geophysical Data Center (NGDC).

The original eighth mesh hemispheric geography data sets were based on coastline coordinates supplied by the Defense Mapping Agency (Fye, 1978). At AFGWC, the static geography files are supplemented each week with sea ice information received from the Navy. Only water boxes are converted to sea ice (and given a geography designator of 2). The final geography data sets in use at AFGWC therefore contain designators for off-hemisphere, water, land, sea ice and coastline.

2.2 Navy 10 Arc Minute Data

NFNOC produced the global 10 arc minute resolution terrain elevation data manually from cartographic materials. The primary sources were the DOD Operational Navigation Charts (although in areas where ONCs were not available, Jet Navigation Charts and World Aeronautical Charts were also used). Error checks were performed both by NFNOC and NCAR.

Modal, minimum, and maximum terrain elevations are provided for each 10 arc minute by 10 arc minute region on the globe (though the true resolution of the data is 20 arc minutes between 70° and the poles). The elevation values are provided in hundreds of feet and (although not explicitly stated in the documentation) it is probably safe to assume that the vertical accuracy of the data are not any better than ± 100 feet. The modal and maximum values are believed to be fairly accurate since any problems identified by users over the past 10 to 15 years have been corrected as they were identified. The minimum elevation data set is considered less reliable and contains some inconsistencies (such as coding all water surfaces as zero regardless of the true elevation of the body of water). The Navy 10 arc minute data set also includes a land characteristics file with a number of descriptive parameters including the percentage of water, the primary and secondary attributes of the geography (ocean, desert, ice, lake, marsh, flat, rugged mountains, valleys, etc.), and the percentage of urban areas (the urban percentages have not been updated over the years and therefore are extremely unreliable). Although the descriptive files handle the basic distinction between land and water, the more explicit assignment of land attributes is not considered totally accurate.

3. DATA MANIPULATION

The original AFGWC eighth mesh terrain data sets supply a terrain elevation characteristic of each eighth mesh gridpoint (the upper left-hand corner of a gridbox). The RTNEPH however, operates primarily on input data representative of an entire gridbox rather than data representative of the area around a gridpoint. Therefore the GL eighth mesh terrain data were prepared to reflect the terrain elevation characteristic of the center of each gridbox.

3.1 Terrain Elevation Data Sets

The latitude and longitude of the center of each eighth mesh gridbox were calculated first. The four nearest 10 arc minute elevation values surrounding that latitude and longitude were extracted from the Navy 10 arc minute data set. The terrain values (which are reported in feet) were converted to meters. Coastal regions in the Navy 10 arc minute data sets are often associated with a terrain elevation of zero feet, making them indistinguishable from the zero mean sea level height of the oceans. Therefore, for each zero terrain height, the Navy 10 arc minute characteristics file was consulted and if the value was listed as a land point rather than an ocean point, the terrain elevation was set arbitrarily to one meter. Land locked regions of the globe lower than sea level remained as negative terrain elevations. Using the four extracted points, a bilinear interpolation was performed to compute a representative terrain elevation that could be assigned to the center of each gridbox. If three of the four surrounding points were assigned zero terrain heights and listed as oceanic points, then the gridbox was set to zero meters (ocean). In this manner, the eighth mesh boxes were filled with terrain elevation values box by box (see Figures 1b, 2b, and 3b). The resultant hemispheric GL terrain elevation data sets were exhaustively compared with cartographic materials to ensure that a more accurate representation of the globe's topography had been produced. The data are provided at the nearest whole meter. The vertical accuracy is no better than the source data (which was assumed to be +100 feet or +30 meters).

3.2 Geography Data Sets

Once the terrain elevation data sets were prepared for both the Northern and Southern Hemispheres, separate geography data sets were prepared. First, all zero elevation GL eighth mesh gridboxes were defined as ocean/water (with a geography value of zero) and all land boxes (with a terrain height of greater than or less than zero) were set to a geography value of one . All off-hemisphere gridboxes were set to minus one. Then, again using the land characteristics of the four 10 arc minute values used in calculating the center elevation, those non-ocean boxes described as containing more than 80 percent water were redefined as lakes and also set to the water geography value of zero. Finally, all land boxes bordering water boxes were defined as coastlines and assigned a geography value of three. The resultant GL hemispheric geography data sets are static files containing designators for off-hemisphere, water, land and coastline (see Figure 4). The geography data sets are aligned consistently with the GL terrain elevation data and have been compared extensively with cartographic sources.

The GL terrain elevation data sets and geography data sets identify many more oceanic islands and intercontinental lakes than do the AFGWC data sets currently in use. One notable exception (obvious to North American users) is the failure of the geography file to identify the Great Salt Lake. Although the terrain elevation of the region is appropriate, the descriptors retrieved from the Navy 10 arc minute characteristics file for the Great Salt Lake and the surrounding salt flats did not pass the 80 percent water test and therefore the region was not classified as water. For the RTNEPH, where the geography file is used to determine the expected reflectivity or thermal response of the satellite imagery, it may be worthwhile to manually switch the value of eighth mesh geography box nearest to the Great Salt Lake's location to zero (water).

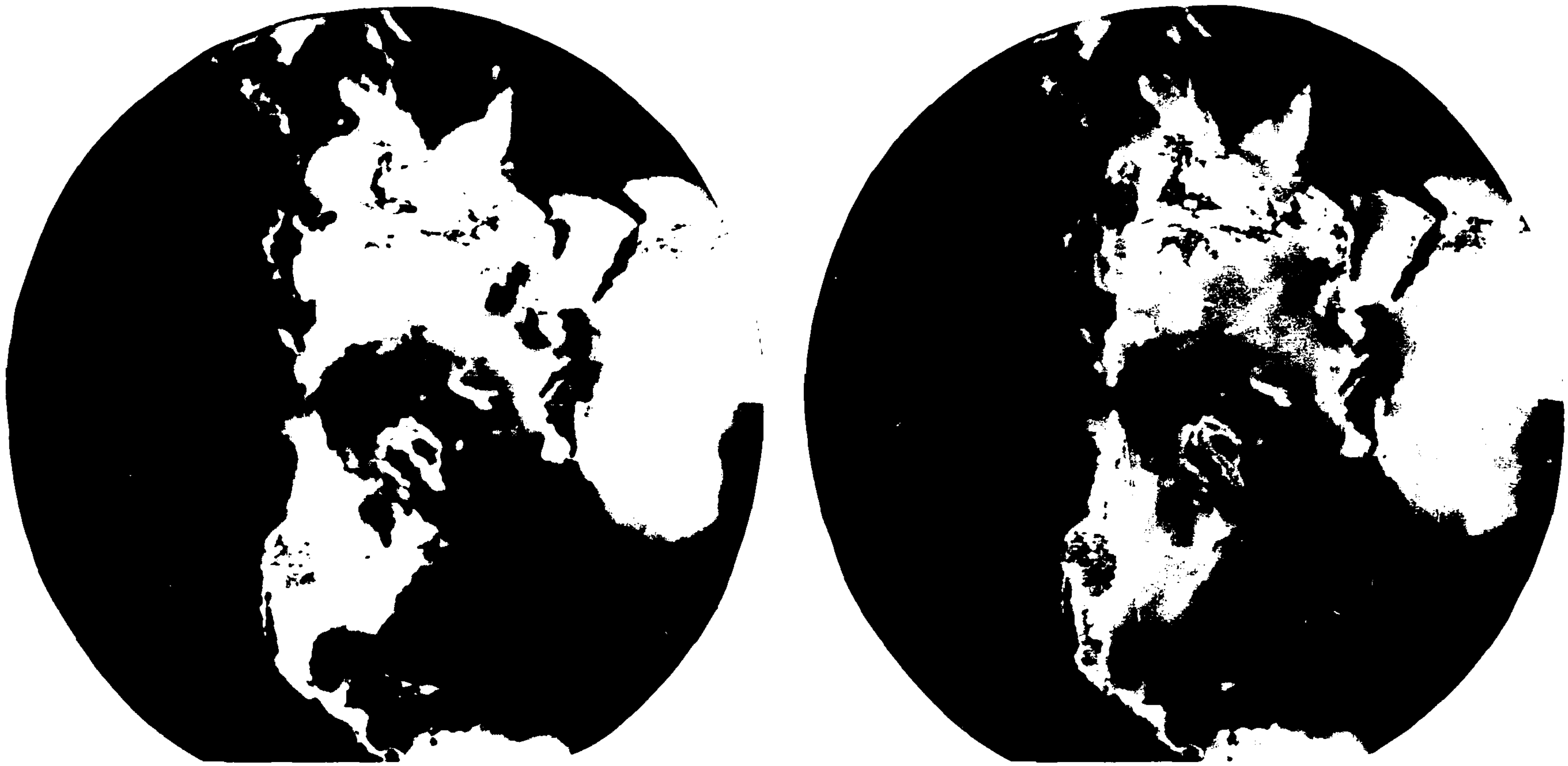


Figure 1. Old (a.) and New (b.) Versions of the Eighth Mesh Terrain Elevation Data for the Northern Hemisphere.

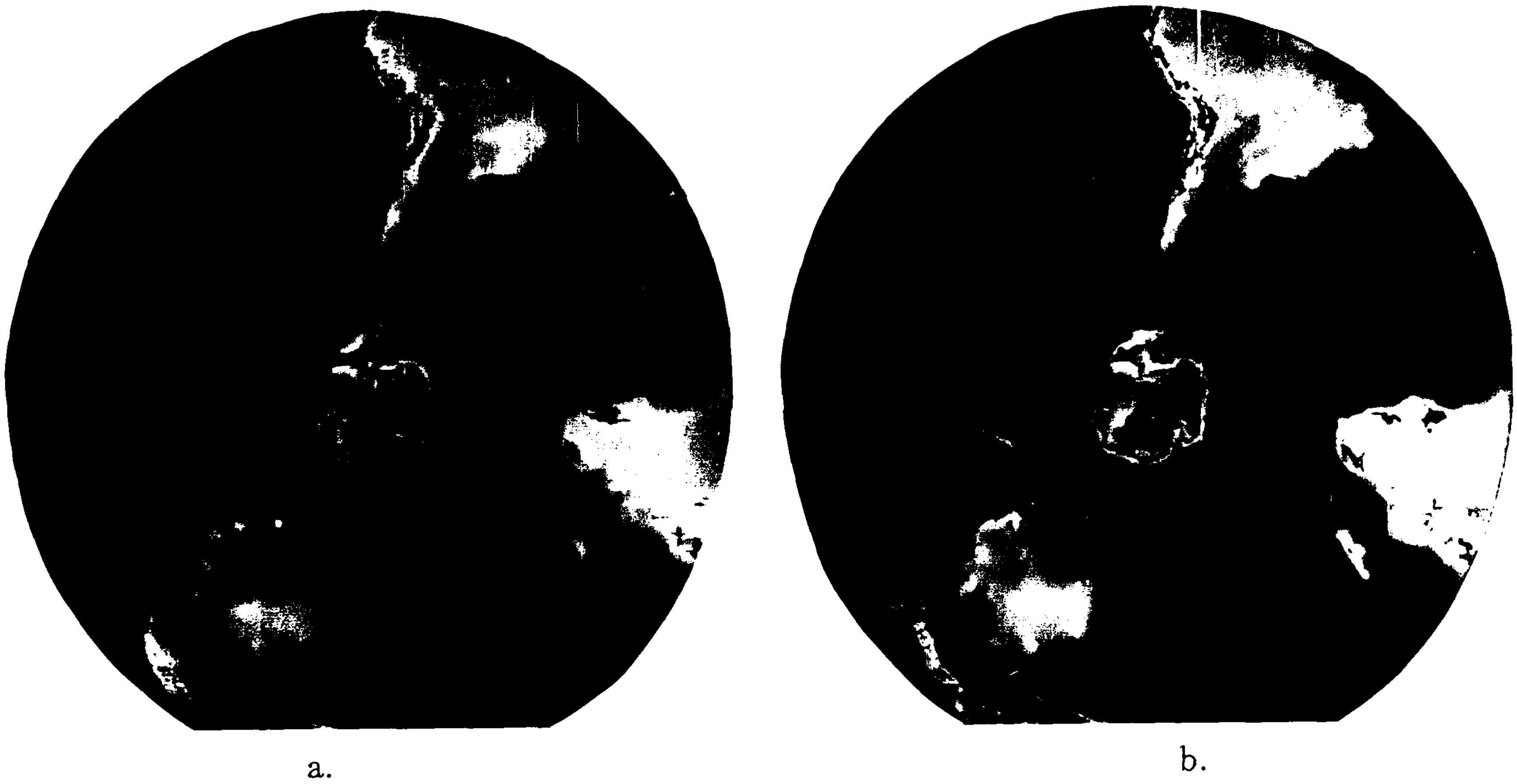
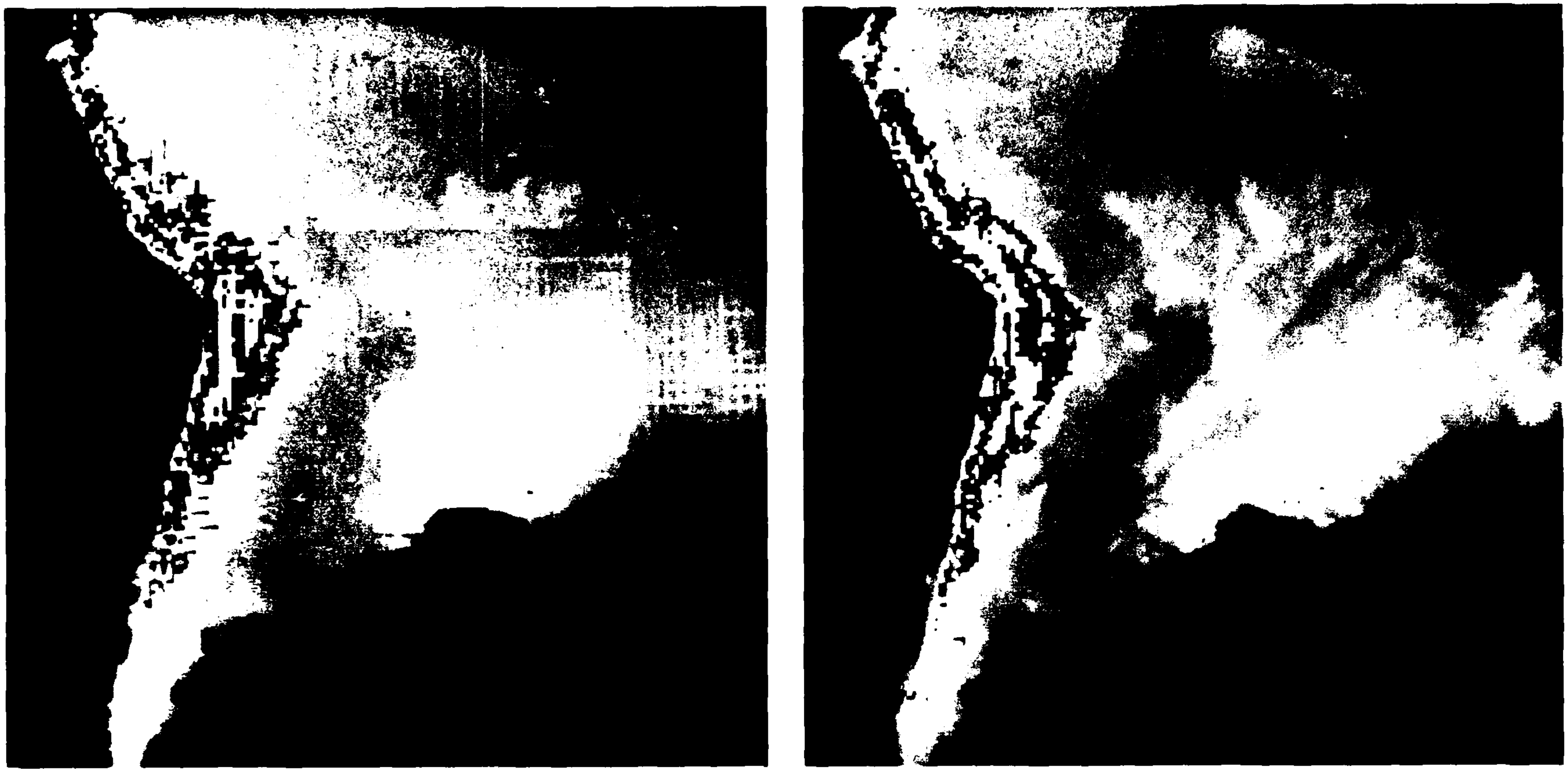
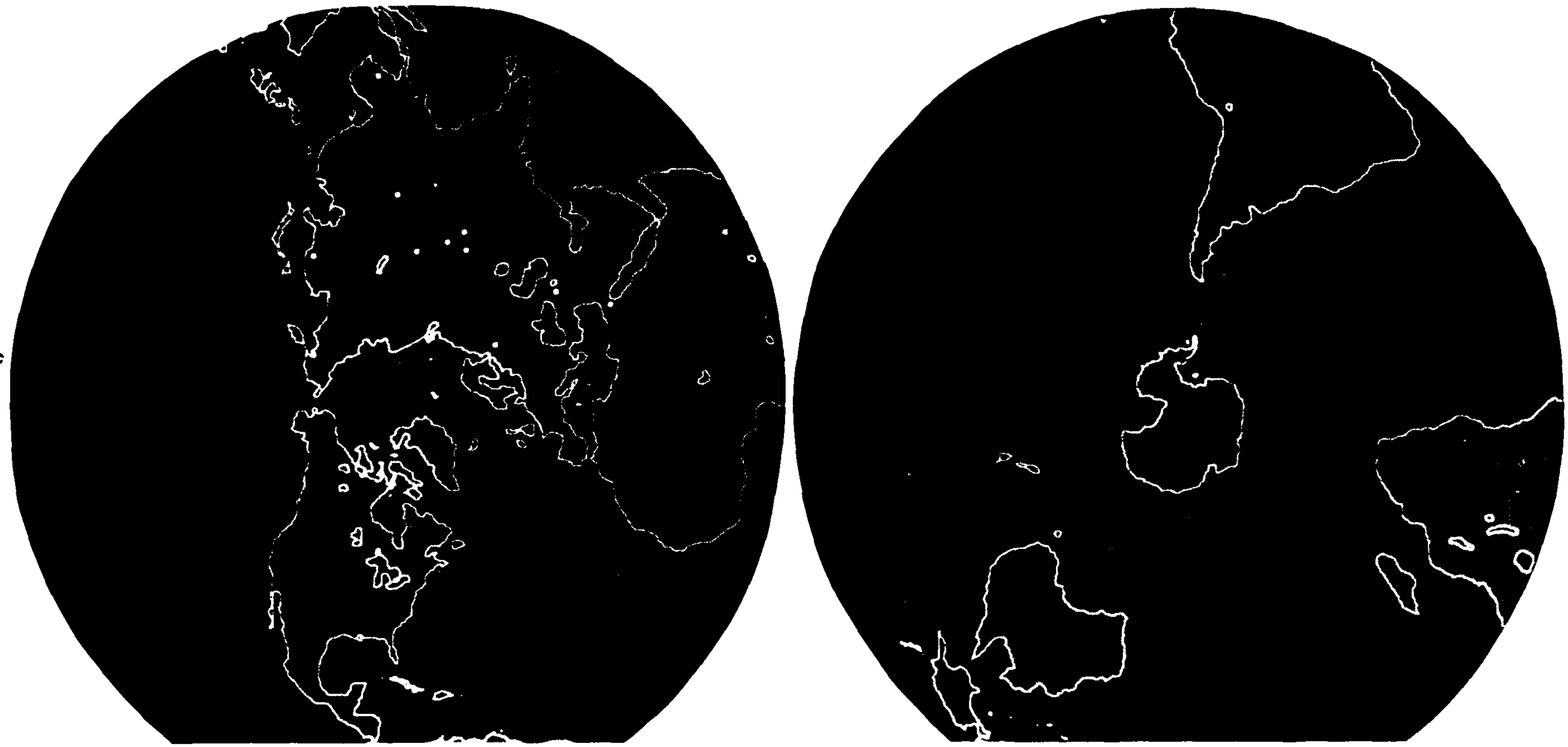


Figure 2. Old (a.) and New (b.) Versions of the Eighth Mesh Terrain Elevation Data for the Southern Hemisphere.



a. b.

Figure 3. Old (a.) and New (b.) Versions of the Eighth Mesh Terrain Elevation Data for South America.



a. b.

Figure 4. New Versions of the Eighth Mesh Geography for the Northern (a.) and Southern Hemispheres (b.).

4. SUMMARY

New hemispheric eighth mesh terrain elevation data sets and geography data sets were developed by GL in support of in-house efforts to enhance the RTNEPH cloud analysis model. The eighth mesh data are based on the Navy 10 arc minute terrain elevation and land characteristics data set. Copies of the new eighth mesh data have been made available to AFGWC and NOAA/NESDIS.

The RTNEPH is an automated cloud analysis model that uses polar-orbiting satellite imagery (primarily infrared) and conventional cloud observations to determine cloud amount, height and type over the globe. Geography data (which are required to determine the boundaries between land and water surfaces) and terrain elevation data (which are necessary to determine the depth of the atmosphere between the surface and space) are used throughout the cloud analysis. Geography information is used in correctly interpreting visual satellite imagery and in making realistic cloud layer decisions. Terrain elevations play an important role in the portions of the RTNEPH model where conventional cloud observations are combined with the automated satellite cloud analysis. Preliminary tests also indicate that the use of incorrect terrain elevations can cause the RTNEPH to assign inappropriate *cloud top heights to cloudy eighth mesh boxes* (Schaaf *et al.*, 1990).

The RTNEPH requires accurate surface skin temperatures to correctly evaluate infrared imagery and make decisive clear/cloud determinations. Skin temperatures are provided by the AFGWC Surface Temperature Model which is also affected by the accuracy of the terrain elevation and geography information. The largest contribution that the new data sets make in enhancing the RTNEPH may be in an indirect fashion by increasing the realism of the Surface Temperature Model output.

Although GL produced the new terrain elevation and geography data sets primarily to improve the RTNEPH, it is hoped that the other AFGWC models that use these data sets will also benefit.

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