**Report No. 3a** **DATA**

# The Case for a 3-minute Climate Surface for South America

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See also Addendum Report (Report 3b) written in January 2004 and based on new information.

**Background:**

Climate surfaces at 0.05º resolution have been produced for much of the World's land surface. Many of these have been produced using the ANUSPLIN software developed by the Centre for Resource and Environmental Studies at the Australian National University under the direction of Dr Mike Hutchinson. Areas with climate surfaces developed in this manner include:

- Africa (Hutchinson *et al.* 1996a) 3-arc minute
- Madagasca 3-arc minute
- Australia (Hutchinson and Kesteven 1998) 3-arc minute (and well as 9 arc-second)
- New Zealand (1996).
- China, Thailand, Vietnam, Laos, Cambodia and the Malay Peninsula (Zuo *et al.* 1996) – 3 arc minute
- Indonesia (Jovanovic and Booth 1996a) 3-arc minute
- The Philippines (Jovanovic and Booth 1996b) 3-arc minute
- North America (McKenney 2000) 3-arc minute. There is also a 2.5 arc-minute coverage of the USA developed using PRISM software (Daly *et al.* 1994).
- Canada (McKenny 2000, Canadian Forest Service 2003)
- Russia – in progress
- Guyana – 1 km resolution (Funk and Richardson 2002).

It would appear that South America is one of the last great regions of the world not covered. Climate surface coverage for South America to date have been at a resolution of 10' of latitude (Jones 1991) or greater as part of an efforts for a global climate surface at 10' resolution (Hijmans 1999, New *et al.* 2002). These efforts however used limited climate data and/or are at a resolution of 10' rather than the 3' resolution proposed here.

Once available, climate surfaces and grids can be used for a variety of ecological and other applications, including the prediction of the distribution of plant and animal species (Nix 1986, Busby 1991, Peterson 2001), climate change studies (Chapman and Milne 1998), modelling the spread of diseases (Bryan *et al.* 1996, Peterson *et al*. 2002), environmental monitoring (Chapman and Busby 1994), agriculture and food production (Nicholls 1997), water resources and hydrological studies (Arnell 1999), the setting of conservation priorities (Chapman and Busby 1994, Faith *et al.* 2001) and the development of ecological regionalisations (Thackway and Cresswell 1995). An environmental or niche model is only ever as good as the input data, and in this case as the environmental layers on which the models rely. Many studies are finding that the environmental layers available are too broad for regional studies and in some cases for studies covering greater areas. The relatively low resolution of the environmental layers do not allow for the discrimination of the relevant environmental niches and thus allow for robust models.

The need for effective integration of GIS and environmental modelling is probably greater in the developing world than elsewhere (Booth 1996). This is particularly so in South America with large biologically unexplored areas subject to great environmental stress. The development of finer resolution surfaces for South America will assist in the improved modelling of these areas, and aid in their long-term conservation. Such surfaces will also aid in the further refinement of global climate surfaces, which in turn will allow for more wide-ranging studies and better comparisons across and between continents.

**Options:**

There are several ways climate surfaces could be built for South America. Already work is underway looking at surfaces for São Paulo State in Brazil and in Brazil itself, but virtually nothing has been considered for South America as a whole.

Climate surfaces could be built state by state, country by country until South America was completed. However, doing it this way, one is unlikely to develop a consistent coverage for the whole continent. Surfaces would likely be at different scales, use different software and technologies to create them, and be of varying quality and consistency.

ANUSPLIN (Hutchinson 2001) is a technique developed in the 1980's and has been refined since. It is a proven methodology, and one that has achieved wide acceptance across the world. The cost to the user is not all that high, and most of the work can be done "in-house". The advantages in using the ANUSPLIN methodology over the others mentioned below, is that the surfaces created would be consistent with surfaces in other parts of the world and it would be using a tried and proven methodology.

Other surface-fitting algorithms have been used in various parts of the world and have produced useable surfaces. These include GIDS (Nalder and Wein 1998) and the CIAT methodology of Jones (Jones *et al.* 1990, Jones 1995).

A comparison of GIDS and ANUSPLIN by Price *et al.* (2000), in Canada, concluded "the ANUSPLIN method … proved generally superior to the GIDS method. … Both subjective assessment and statistical analysis showed that ANUSPLIN is generally more accurate in predicting climate variables at the locations of climate stations withheld at random from the source datasets". They also concluded that ANUSPLIN produced better smoothing and better gradients at high elevations and where climate station coverage was poor.

The CIAT method uses a simple interpolation algorithm based on the inverse square of the distance between the station and the interpolated point of the nearest five stations (CIAT ndat.). The method has the advantage of speed and ease of use for large data sets where there is limited computational capacity (Booth and Jones 1996). Booth and Jones suggest that "more complex interpolation algorithms (e.g. Laplacian splines) are better interpolators, but need more computing power". They go on to say that "the major difference between the techniques used by CIAT (Jones *et al* 1990) and CRES (Hutchinson 1989) is that the CIAT method uses a standard lapse rate applied over the whole dataset; the CRES method uses a 3-dimensional spline algorithm to determine a local lapse rate from the data". They conclude that ANUSPLIN provides a powerful set of programs for climatic analysis.

**Data Requirements:**

***DEM***

A good digital elevation model (DEM) is a prerequisite for most climatic interpolation studies (Booth and Jones 1996). A few years ago the USGS developed a DEM covering all the earth's land masses at 30-arc second (approx. 1 km) resolution (Verdon and Jenson 1996). These are now available for down-load from the internet free of charge (NGDC 2000). The availability of a DEM at this resolution makes the preparation of climate surfaces at the proposed scale possible, given the requisite meteorological data.

Advice I have received (McKenney pers. com. 2003) would indicate that there are some significant errors in the USGS DEM. He suggests that there is good reason to create a new DEM using ANUDEM (Hutchinson 1989b, 1996b, 2003) software prior to attempting to create surfaces. This may need to be considered.

***Meteorological Data***

The more meteorological data one has, the better the surface that is likely to be able to be produced. Two of the largest global meteorological databases are maintained by the Centre for Resource and Environmental Studies (CRES), Australian National University in Canberra, Australia and the Centro Internacional de Agricultura Tropical (CIAT) in Cali, Colombia (Booth and Jones 1996). There has been considerable exchange of data between the CRES and CIAT databases and in 1996 they both held data for over 25,000 locations around the World (Booth and Jones 1996).

New *et al.* (2002) provide maps of meteorological stations around the globe that provide data on a range of variables such as wind speed, rainfall, diurnal temperature, etc. If one examines those maps, perhaps the greatest deficiencies of weather stations for South America are in the Cerrado and Amazonian regions of Brazil and Patagonia in Chile. Additional data covering these areas may be obtainable from local sources within those countries. If one compares the desert areas of Australia, however, where climate surfaces have been developed at much finer than 3-arc minutes, holes such as these in the coverage can be catered for using the spline software.

## ANUSPLIN

ANUSPLIN is a Fortran program for the application of multi-dimensional thin-plate splines using up to 10 independent variables. Most applications routinely incorporate spatially and temporally varying dependence on elevation. For detailed explanations of how ANUSPLIN works see Hutchinson (1996), Kesteven & Hutchinson (1996) and Hutchinson *et al.* (1996b).

Examples are also available showing the process of creating climate surfaces using this method for Australia (Hutchinson and Kesteven 1998) and for Africa (Hutchinson *et al.* 1996a) and some of the problems are highlighted.

### Why 3-arc minutes

The question may be asked as to why one would select a resolution of 3-arc minutes when a 30-arc second Digital Elevation Model (DEM) is available. There are several reasons:

- There is a massive increase in computing power needed to prepare and use GRIDS at 30-arc seconds as opposed to one at 3-arc minutes
- The accuracy of the majority of species distribution data (and especially historic museum and herbarium data) can generally be regarded as no better than about 5 km (Chapman and Busby 1994, Chapman 1998). Thus to use finer surfaces for species modelling could be misleading and lead to significant errors.
- Most of the rest of the world's land areas has climate surfaces at 3-arc minutes, and surfaces prepared for South America would help complete a coverage for the globe at this scale.

### Conclusions:

In a study in 1999 that compared a number of methods for interpolating climate surfaces using Mexican data (Hartkamp, *et al.* 1999) the authors concluded: "Taking in account error prediction, data assumptions, and computational simplicity, we would recommend use of thin-plate smoothing splines for interpolating climate variables".

### Resources:

***Software***
Purchase of software: R$2,500

***Computational***
Computer
Cost of Climate Data

***Human***
Staff resources for ???
Cost of bringing visiting scientist from the Australian National University to Brazil for 3 months

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