PC-TOVS: a desktop PC program for the extraction and analysis of TOVS data

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Abstract

The development of low cost reliable, PC-based satellite reception systems has enabled developing countries to access data which are used to enhance their natural resources management programmes. The atmospheric profile data provided by TOVS are especially versatile. NRI has developed and field-tested a PC-based TOVS extraction and analysis program, in collaboration with the University of Wisconsin-Madison (using ITPP 4 and 5) and the British Antarctic Survey. Users can display wind, temperature, dew point and geo-potential height data at selected pressure heights, or map total column water vapour and ozone, horizontally, as well as display associated NOAA/ AVHRR imagery; all within minutes of local data reception. Vertical profiles of dew point and temperature can be extracted for the TOVS sounding points. Displayed data can be printed, or incorporated into other geographical analysis programs. The operation of PC-TOVS is demonstrated by reference to a study from Punta Arenas, Chile. The further potential software is discussed.

INTRODUCTION

It is well known that the annual breakdown of the stratospheric ozone layer, first reported from Antarctica over ten years ago, is continuing (Farman et al, 1985; Jones and Shanklin, 1995) and that a similar, but currently less severe, process now occurs over the Arctic (von der Gathen et al, 1995). The biological consequences of increased ultra-violet radiation are still being investigated but many potential effects have been discussed (eg Wyman, 1991) and public awareness and concern is increasing. The results of ozone monitoring are available through regularly published bulletins and on the Internet, but users in developing countries may not have access to such information, or receive it too late for it to be of practical use for analysis or forecasting. The Natural Resources Institute (NRI) recognised that there was a strong need for a PC-based data extraction and analysis package, accessing ozone and other atmospheric thermodynamic sounding information at source via NOAA High-Resolution Picture Transmission (HRPT) satellite receivers.

Through its Local Application of Remote Sensing Techniques (LARST) initiative, NRI has considerable experience in delivering systems for the local collection and analysis of real-time remotely-sensed data as an aid to environmental monitoring and natural resources management (Perryman, 1996). In 1994, NRI, in collaboration with the Cooperative Institute for Meteorological Satellite Studies (CIMSS), University of Wisconsin-Madison, USA and the British Antarctic Survey (BAS), began development of a PC-based package which would enable the extraction and analysis of TOVS data. The principle requirements of the software were that it should be appropriate to developing country locations (relatively cheap, robust and maintenance free), and hence useable worldwide and that it could be operated using relatively simple software. The result of this, PC-TOVS, is a DOS-based menu-driven program with a graphical user interface.

The software

The PC-TOVS software comprises three parts. The first is designed to extract and geolocate the TOVS data from the raw NOAA-AVHRR-HRPT data stream and derive the meteorological parameters. The other two (graphics) components allow users to examine the results and intermediate products of the extraction: one permits the viewing of processed meteorological parameters and the other the simultaneous viewing of, for example, calibrated HIRS, Microwave Sounder Unit (MSU), and NOAA-Advanced Very High Resolution Radiometer (AVHRR) channel information.

Data extraction

The extraction component is based on selected programs and sub-programs from the program suite comprising Version 4.02 of the International TOVS Processing Package (ITPP) developed and distributed by CIMSS. The ITPP code for the analysis was developed in FORTRAN, as has the PC implementation of the analysis component in PC-TOVS.

The design and installation of the PC-TOVS software and the location of the ancillary files required for the successful running of the package have been organised in a manner to be consistent with the HRPT reception and processing system developed by Bradford University Remote Sensing Unit (BURS) (Figures 1 and 2). Within the analytical components of the software, there are programs which allow the extraction of the TOVS data (contained within the TIP data) of the NOAA-AVHRR-HRPT data stream. The main extraction program (PREING) extracts the relevant information from the BURS 'Block' data files. These files contain: raw TIP information (excluding HRPT data), data for each AVHRR sensor channel, with a histogram of values for each channel, and NORAD TLE orbital data. For data not being accessed in the BURS format, there is also a program that allows the reformatting of TIP data as acquired from a system supplied by the University of Dundee for the BAS and others (PREING_A). After extraction of the necessary TIP data, they are calibrated and geolocated (INGTOV); pre-processed (TOVPRE); and the vertical profiles of atmospheric temperature, humidity, geopotential height, ozone and various other parameters are determined. This last task can be done by fast statistical retrieval (TOVSTR) or by a more robust, physically-based method (TOVRET).

Data extraction is performed through either of the 'All Processes' or 'Individual Processes' options (Figure 2). Selection of All Processes runs all the processes shown in Figure 1 sequentially. The users may specify to do this automatically using all the system defaults (see following sections) or they may select to run through all the functions interactively (ie having the opportunity to alter input parameters of any of the individual processes and to view the results before proceeding to the next process). Individual Processes permits users to run each of the processes shown in Figure 1 individually, having full control of changing the input parameters and the mode of retrieval, of viewing the results of each process as it is completed and even of repeating or re-running processes. If this option is chosen, another menu is presented which allows users to select which of the processes to extract. The user, therefore, has full flexibility (and therefore responsibility) to run the processes in a meaningful order.

Data presentation

Both graphics components have been developed in 'C' and 'C++' using routines that access the super-VGA (800x600x256 colour resolution) capability of modern PCS. Selection of the View TOVS Products' option from the main menu (Figure 2) allows the user to run TOVSPLOT and view the TOVS meteorological products, as vertical profiles or by mapping horizontally.

Graphical examination of the extracted data is based on a selection made by the user from the analysed 'Block' data file. Initially, the data are presented as a map showing the coastlines and country borders relevant to the plotted area. The location of all the TOVS retrievals contained in the selected retrieval data file are also plotted, with a cross to indicate the location, and a number beside the cross to indicate the number in the file to which the retrieval corresponds (Figure 3). A menu presents the latitude and longitude values for the four corner points and smaller areas within the display may be selected. Two geographical projections are available: simple latitude/ longitude or polar stereographic. In either case, the maximum latitude and longitude extents of the data set chosen are calculated, and the scale parameters to fit most data to the screen are calculated automatically. For the polar stereographic projection, the prime longitude is calculated to allow the data to be presented centrally on the screen.

Data may be examined either as tephigrams or T-log(P) according to user requirements. Temperature lines ranging from -50 to +50°C and pressure lines from 100 hPa are shown on the tephigram or T-log(P) plot. The retrieval air temperature-pressure values are plotted as a yellow dotted line, and the dew-point values (up to 300 hPa) are plotted as a white dotted line. The TOVS retrieval number, the data and start time of the data set, the latitude and longitude (in decimal degrees) of the TOVS retrieval being plotted and the surface elevation at that point (in metres as extracted from the global topography database) are shown beside the plot. Calculated values of the surface (skin) temperature estimate (°C), the stability index (°C), the total column precipitable water (mm) and

ozone (Dobson Units) are also indicated (Figure 4). A value of 999.99 is recorded for any parameters missing or which or which can not be calculated.

Plotted values may be saved to an ASCII file for expert to another package or printout. The data are stored with the TOVS retrieval number (relative to the file from which it is obtained), data, time and latitude/longitude of the retrieval. The data values plotted are the air temperatures (Kelvin) for the standard meteorological levels from 1000 hPa to 50 hPa, and dew-point temperatures for 1000 hPa to 300 hPa. Radiosonde data, held in separate files, may also be added to the tephigrams. On completion of the tephigram, users may continue with further tephigram plots, or examine the horizontal spread of the data.

Any of the following may be plotted horizontally, with the basic 10 VGA colours being used to indicate gradations: (I) air temperature (°C) at standard levels, and the temperature difference between any two levels; (ii) dew-point temperature (°C) at standard levels, and the difference between any two levels; (iii) geostrophic winds (knots) at standard levels from 850 hPa; (iv) geopotential heights (thickness in m) at standard levels, and the difference between any two levels; (v) precipitable water (mm) of the total column; (vi) ozone (Dobson Units) of the total column.

With the exception of the geostrophic wind plots (see below) the value of the selected parameters is written adjacent to the cross that denotes the location of that retrieval. The satellite identification and orbit details are also given in the screen header information. An ascending orbit (south to north) is denoted by ASC: DESC denotes a descending (north to south) orbit.

Data plotted on the screen may be interpolated. Once the interpolation is completed, the user is presented with a legend showing the values and their assignments to colours in any case. The coastlines latitude/longitude graticule and country borders are redrawn over the interpolated image (Figure 5). Plotted values may also be saved to an ASCII file, where the data are stored in three columns: longitude and latitude of each point for which there is an estimate of the relevant parameter, and the values of that parameter.

For geostrophic winds, once the user has selected the level, arrows representing the direction and strength of the winds are drawn at the locations for which they were calculated. The length of each line is constant and scaled to represent the distant between TOVS retrievals. The orientation of the line from north represents the direction. Wind strength is denoted by the tails of the arrow, in increments of 5 knots. Derived wind vector data may be superimposed on the displayed horizontal parameter information, whether this has been interpolated or not. The user may display thermal winds from any level on interpolated surfaces of any parameter at any level.

The other graphics option (TOVS multi-view) enables the simultaneous viewing of TOVS HIRS or MSU channel information along with NOAA-AVHRR imagery and other parameters in five windows, or viewports. Once a viewport has been made active, combinations of MSU, HIRS, AVHRR, Bidirectional reflectance (BDR) and Outgoing Longwave Flux (OLWF) data may be displayed.

Use of PC-TOVS as an aid to weather and ozone forecasting over southern Chile

Low stratospheric ozone levels over southern South America in the austral spring directly increase surface ultra-violet light levels (UV-B), which is hazardous to human health and of great public concern. Between 1994 and 1996, NRA and BAS were involved in a co-operative project with staff from departments of the Universidad de Magallanes, Punta Arenas (UMAG): Groupo Ozono; Centro Austral Antarctica; Instituto de Patagonia and the Centro de Estudios de los Recursos Energéticos, to use PC-TOVS in improved real-time monitoring and forecasting of stratospheric ozone levels and to aid the development of an early warning system for low levels of ozone to benefit the public, by forewarning of high UV-B conditions. This investigation also permitted rigorous field testing of the program's outputs.

The TOVS-derived ozone maps clearly showed the ozone hole over Antarctica during October 1995. These could be used to issue a short-term forecast, valid for about 12 hours, as and when the elongated hole approached Punta Arenas by regularly monitoring its movement. Such an approach, however, was not possible for developing longer-range forecasts. Accordingly, a novel regional-scale ozone level forecasting scheme was developed for use at UMAG, based on the relationship between stratospheric ozone levels (measured by TOVS) and stratospheric

temperatures (from TOVS and from large-scale weather forecast model outputs becoming available via Internet) to provide 48 hour forewarning of locally reduced ozone levels (Lachlan-Cope et al, in prep). PC-TOVS is being used by the weather service at Punta Arenas to further improve their weather forecasts, especially over the southern Atlantic and Pacific Oceans (from 45oS to Antarctica) where ground data are sparse.

Groupo Ozono had previously been monitoring ozone concentrations and issuing statements of high UV-B levels to the regional government and to the public, via the media in the days following low ozone events. This project has enabled them for the first time to issue warnings of severe conditions up to 48 hours before the events.

Future developments

PC-TOVS is currently being modified to permit the extraction of TOVS data from the NOAA-14 satellite and to enable users to input regional climatological data and surface observations, which may be displayed alongside the TOVS information. Development of a similar program, to process ATOVS data, is being actively considered.

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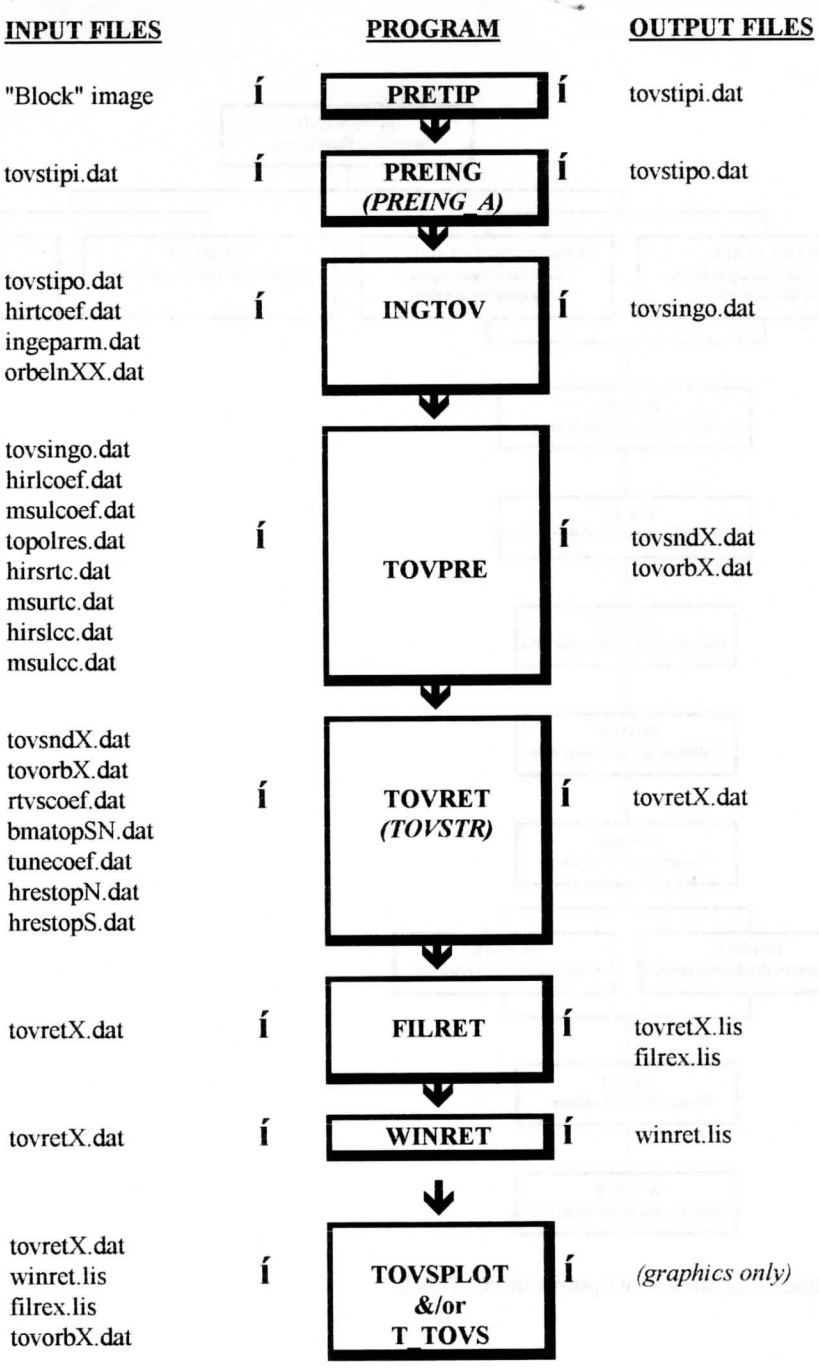

Figure 1. Flow-diagram illustrating sequence of ITPP TOVS analysis routines and their relevant input and output files. 'X' indicates a variable character which is assigned by user. Alternate programs to the conventional ones (*i.e. PREING_A, TOVSTR*) are indicated in brackets and italics.

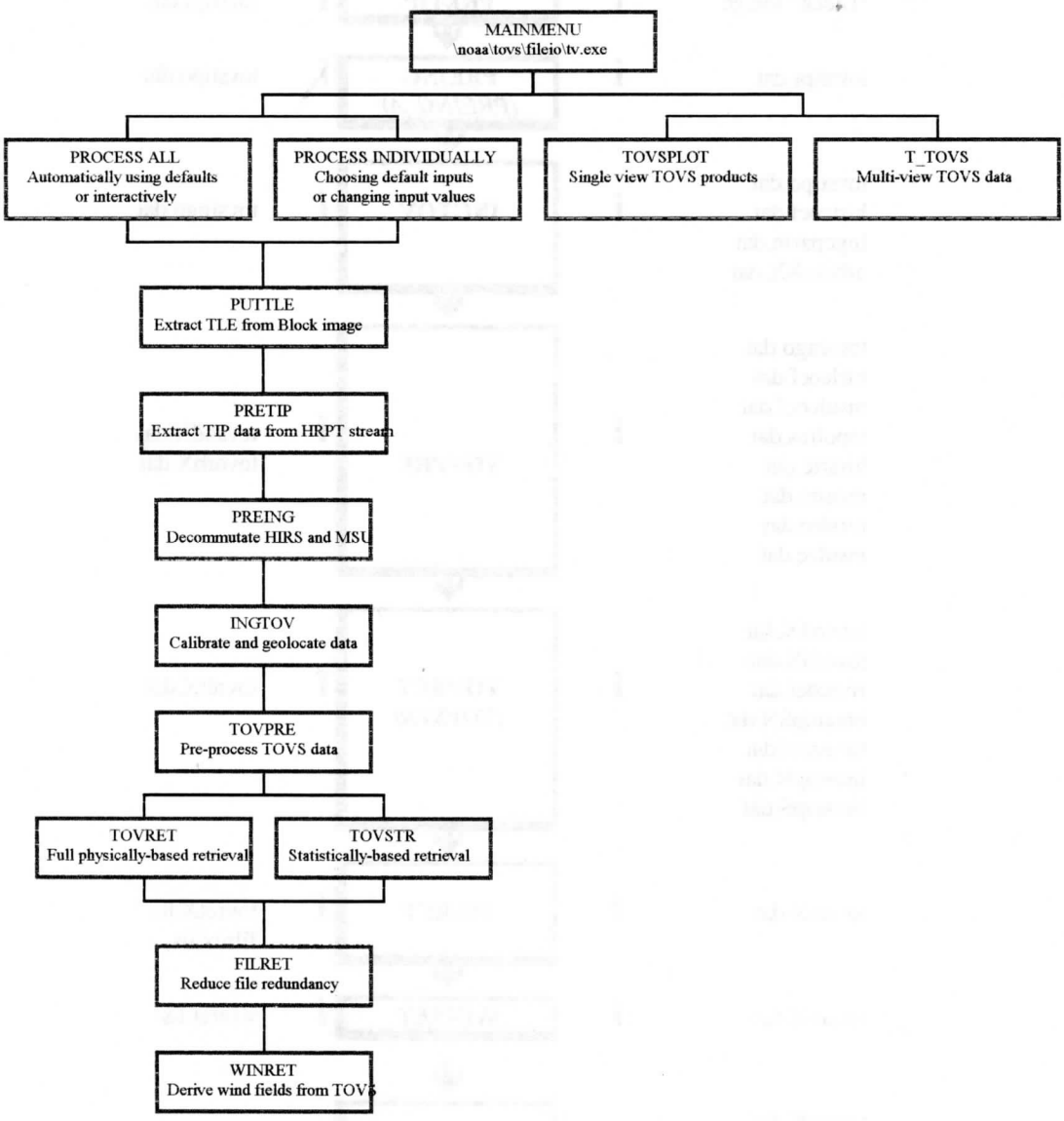

Figure 2. Outline of menu-driven options in PC-TOVS

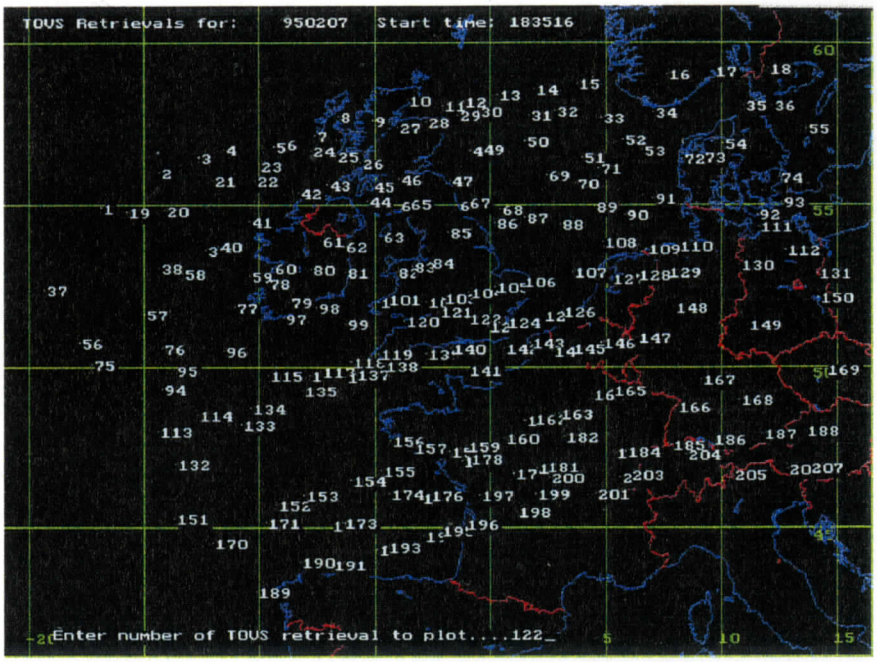

Figure 3. Map showing TOVS retrieval numbers and country overlay.

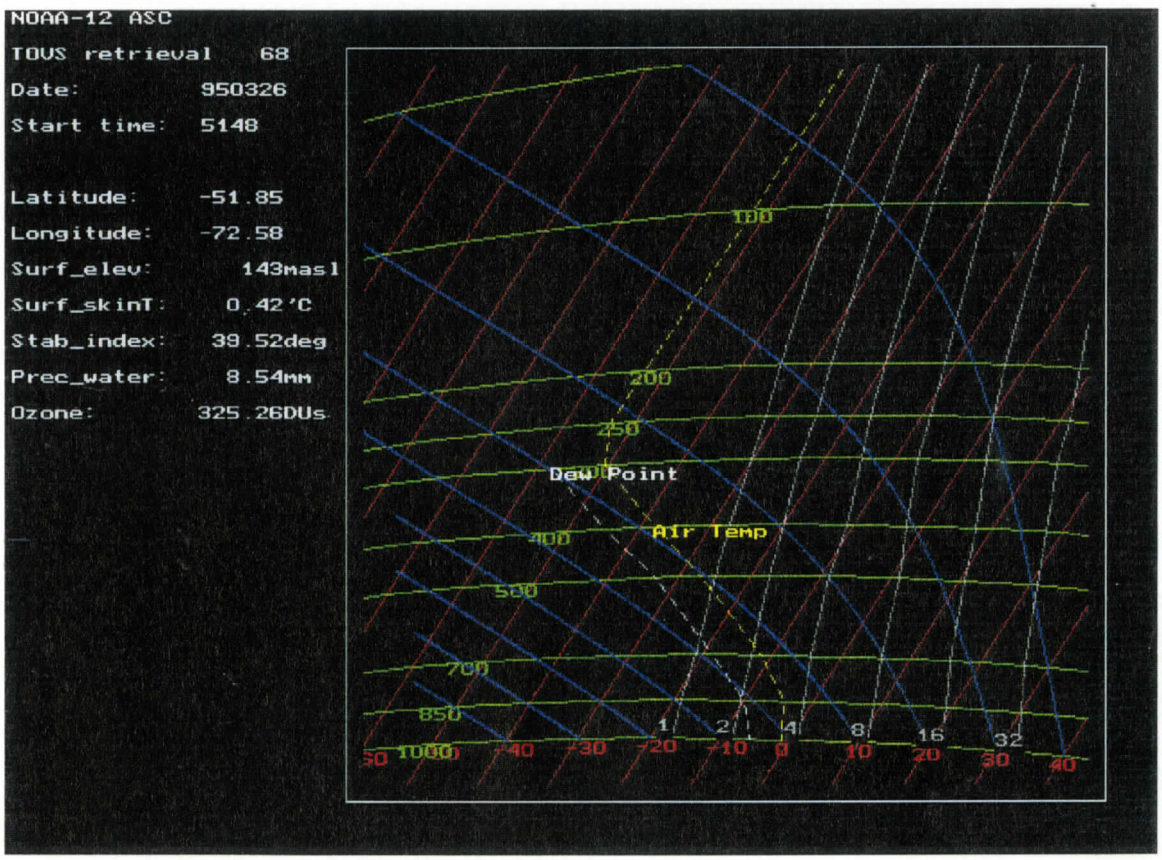

Figure 4. Vertical profile extracted from single TOVS sounding

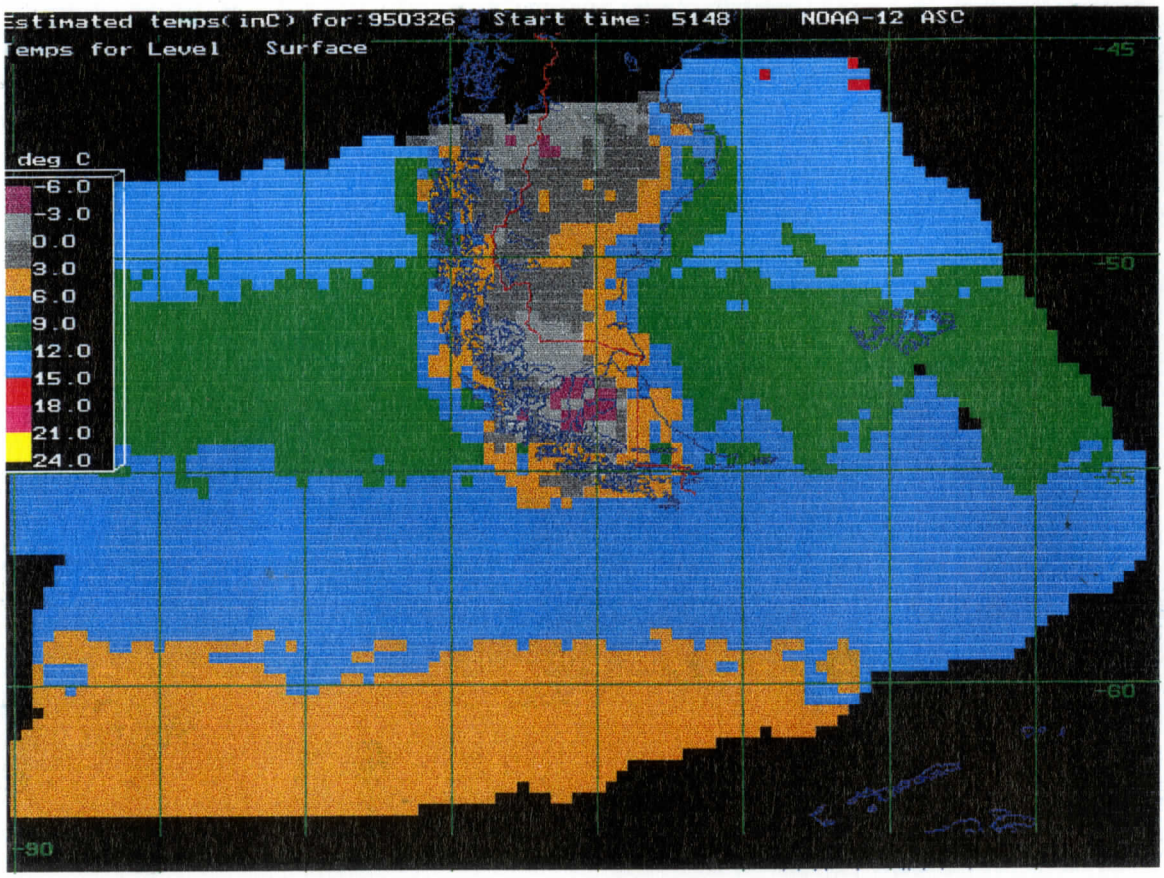

Figure 5. Interpolated temperature plot for southern Chile

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