
BCIT GIS Student Project

**GIS TOOL FOR ANALYSIS OF SPATIAL DISTRIBUTION
OF GRIB METEOROLOGICAL DATA FOR HYDROLOGY MODELING
FINAL REPORT**



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“The rain in Spain falls mainly in the plain.”

An old-times hydrological observation

Abstract

For the BC Hydro it is important to use all available methods of improving the hydrological forecast.

For this purpose in this project we tried to use GIS as a tool for acquiring and distributing meteorological data that will be used for further modeling.

North America Region daily temperatures from Canadian Meteorological Centre were imported from GRIB to ArcGrid format and then distributed spatially using three different methods of interpolation and prediction, determined by multiple regression analysis.

Calculated temperature values were averaged for the Cheakamus basin in whole and for each of its elevation bands. Temperature values were also recorded for the location of the basin weather station (Upper Cheakamus Data Collection Platform).

The work was started on January 6, 2003 and finished on May 18, 2003. The total number of hours used towards completing this project is 709 hours.

As a result there was developed a methodology to spatially distribute the output from a numerical weather model and aggregate the data for future use as input to a hydrologic model. The methodology was tested using temperature data.

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1. Introduction

GIS is a rapidly growing field of technology that incorporates spatial and meta-data in order to assess real-world problems. With the wide availability of global and regional meteorological datasets, GIS has become a powerful tool for delineating hydrological watersheds, analyzing runoff and for other applications in hydrology. Realization of new GIS applications and tools is greatly helping governments and local administrations to manage natural resources in a more efficient and cost effective way.

Continuing improvement of the data collection and data management systems and availability of real time data induce an increasing information potentiality that require significant effort of the local national and international services to maintain an acceptable level of modernization and updating. The geographic analysis and modeling tools provided by GIS allows making informed decisions and becoming more and more necessary with the increasing of phenomenon complexity.

2. Project Statement

The purpose of this project is to:

- 1) develop a methodology to download, convert, and import regional temperature GRIB data into a GIS
- 2) employ various geospatial interpolation techniques
- 3) provide elevation band, basin, and DCP station location temperatures for a test period (35 days)

3. Details of Project Industry Sponsor

BC Hydro, a power company formed in 1945, is one of the largest powers companies in North America. Twenty-seven watersheds in the province have their drainage controlled by 30 hydroelectric plants within the province.

The company is involved in regulation of the flow of river systems at 30 hydroelectric facilities on this 27 watersheds flood management, dam safety and fish habitat preservation. (Our business 2003)

BC Hydro's goal is to become a leading sustainable energy company by producing and delivering electricity in environmentally and socially responsible ways.

BC Hydro provides high-value, reliable power to fuel economic growth in British Columbia. As one of the largest electric utilities in Canada, BC Hydro serves more than 1.6 million customers in an area containing over 94 per cent of British Columbia's population. BC Hydro endeavors to provide energy solutions to its customers in an environmentally and socially responsible way by balancing British Columbians' energy needs with the concerns of the environment. Through the efficient and reliable supply of electricity, BC Hydro supports the development of British Columbia and has constructed a world-class integrated hydroelectric system of close to 11,500 megawatts of generating capacity – over 87% of which is hydroelectric. Due to this efficient, reliable system, British Columbians enjoy some of the lowest electricity rates in the world.

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Telephone: (604) 528-8329

Main Office Address: 6911 Southpoint Drive
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4. Project Objectives

4.1 Project Objectives

The aim of this project is to develop a methodology and provide temperature data for a comparison of elevation band temperatures as distributed by the UBC watershed model and by a GIS.

For this purpose we used GIS as a tool for acquiring and distributing meteorological data that will be used for further modeling.

North America Region daily maximum temperatures from Canadian Meteorological Centre (CMC) were downloaded and imported from GRIB to ArcGrid format and then distributed spatially using three different methods of interpolation – “IDW”, “Spline”, “Kriging” and also prediction, determined by multiple regression analysis.

Calculated temperature values were averaged for the Cheakamus basin in whole and separately for each of its elevation bands. Temperature values were also recorded for the location of the basin weather station (Upper Cheakamus Data Collection Platform).

The results will be used to evaluate whether the vertical temperature distribution currently calculated by the UBC watershed model could be improved by using a vertical temperature distribution as derived by means of a GIS. Eventually this could potentially improve hydrologic modeling and, in particular, hydrologic forecasts.

4.2 Project Deliverables

- Final Project Report
- Final temperature distribution maps, showing Cheakamus basin, the DCP, temperature grid

- Final temperature distribution maps, showing temperature grid, DEM and derived from it slope and aspect grids
- Table of basin average and identified at the DCP location temperatures for each interpolated data set
- All modules written for data conversion
- Description of all procedures
- All raw data

5. Project Background

5.1 UBC model

Each morning of each working day, the BC Hydro forecast team forecasts the daily inflow for the next five days for 20 reservoirs throughout the province. The UBC watershed model (Quick 1995) is a conceptual hydrologic model, which was initially developed in the early 70's. It is currently used by BC Hydro to produce hydrologic forecasts. For a given watershed, the model simulates the various components of the runoff, which include rainfall and snowmelt runoff, glacier melt, and baseflow using daily precipitation, and minimum and maximum temperatures. The model also simulates basin state conditions, such as the snowpack, groundwater, and soil moisture. Together, these components represent the observed and expected inflow hydrograph for the reservoir.

The UBC watershed model is a semi-distributed model. Runoff is not calculated for the watershed as a whole, but it is calculated separately for predetermined elevation bands and the linearly combined to obtain total runoff. However, the UBC watershed model currently uses input data measured and forecast for points, i.e. at individual weather stations. Since temperature and precipitation are, amongst others, dependent on elevation, input data have to be distributed vertically from the elevation of the weather station to the elevation of the elevation bands. "The temperature lapse rate is a key relationship because it

influences the precipitation distribution, and it is also very significant in determining snowmelt rates at various elevations“(Quick 1995: Appendix A-1). Therefore, this project focuses on the temperature distribution. To lapse data vertically, simple assumptions are made in the UBC watershed model. The model calculates the lapse rate separately for minimum and maximum temperatures using the daily temperature range (diurnal range) as an index.

Alternatively, temperatures can be distributed spatially using a GIS and then be aggregated by elevation bands for use in the UBC watershed model. The aim of this project is to develop a methodology and provide temperature data for a comparison of elevation band temperatures as distributed by the UBC watershed model and by a GIS.

5.2 Similar Projects

The only similar project was found in the “Journal of Hydrology” done by Jorge Marquínez, Javier Lastra and Pilar García. Using multiple linear regression and Geographic Information System techniques, they modeled the spatial distribution of mean monthly precipitation for the seasonal and annual periods in a mountainous region of 10,590 km², located in the central area of the Cantabrian Coast, Spain. The best model developed used five topographic descriptors as independent variables: elevation, distance from the coastline, distance from the west, and a measurement of elevation and slope means into homogeneous areas. These topographic variables were calculated as raster models with 200 m resolution.

6. Project Data

6.1 Data Sets

GRIB Data:

GRIB stands for **GRI**dded **B**inary format. It is an efficient vehicle for transmitting large volumes of gridded data to automated centers over high speed telecommunication lines using modern protocols. By packing information into the GRIB code, records can be made more compact than character oriented bulletins, which will produce faster computer-to-computer transmissions.

It is a self-describing data format. That is, each record in a GRIB file will be divided up into sections, with the first few sections of each record describing what data are included in the record (what parameter, what level, what starting time, what forecast time, what grid boundaries, what grid spacing, etc...), and the last section containing the actual binary data. Detailed information about this data format could be found in the Internet. For example NCEP's GRIB Guide is available via web at:

<http://www.nco.ncep.noaa.gov/pmb/docs/on388/download>

WGrib - a program to manipulate, inventory and decode GRIB files is available on the web page of Wesley Ebisuzaki, a researcher at NCEP:

<http://wesley.wwb.noaa.gov/wgrib.html>

(NCEP stands for National Centers for Environmental Prediction)

In March 2003 Canadian Meteorological Centre (CMC) opened access to various meteorological data through the Internet. High-resolution CMC GRIB dataset - Global GEM at 1x1 degree resolution and Regional GEM at 24 km resolution are free, but requires a written agreement with the MSC. The data is available at the following URLs:

Global 00Z, 12Z:

http://dd.weatheroffice.ec.gc.ca/grib/public/hires/CMC_glb_00

http://dd.weatheroffice.ec.gc.ca/grib/public/hires/CMC_glb_12

Regional 00Z, 12Z:

http://dd.weatheroffice.ec.gc.ca/grib/public/hires/CMC_reg_00

http://dd.weatheroffice.ec.gc.ca/grib/public/hires/CMC_reg_12

For this study, daily maximum temperatures were analyzed. Daily maximum temperatures can be approximated with local 4pm temperatures (corresponds to 00Z). Since a verification of the interpolated data is required for this study, data for the 00hour forecast interval was chosen. These were assumed to be the best spatial representation the actual 4pm temperatures. Spatially distributed temperatures for any given grid cell can then be compared to temperatures observed at weather stations to assess the quality of the interpolated data. One specific regional high-resolution GRIB file was manually downloaded every day from the address shown above. Altogether 35 files were collected for the period from March 21 to April 30 this year. Files contain surface temperature grids for the region covering North America and adjacent waters with a 24 km resolution at 60 N.

Table 1.

Regional GEM on full-resolution Polar-Stereographic grid specification.

ni (number of rows)	313
nj (number of columns)	249
resolution at 60° N	24 km
coordinate of first grid point	32.725° N 134.532° W
(i,j) coordinate of North Pole	(109.0, 249.0)
grid orientation (with respect to j axis)	111.0°

From CMC there was also obtained a formatted html file containing geographical coordinates for each grid point.

DEM:

Provided by BC Hydro were 6 Gridded DEM files of 1:250 000 scale maps with 25 meters resolution.

BC Hydro Basins:

Provided by BC Hydro was the shapefile of basins and elevation bands that contained Cheakamus basin – the one it was decided to choose for this project area of study.

DCP:

Provided by BC Hydro was the Microsoft Excel file, containing description and coordinates of every DCP.

Table 2. List of Project Data Sets.

Data set	Type	Purpose	Projection	Accuracy	Location	Data format
Daily maximum temperatures C°	GRIB data	Conversion And Analysis	Polar - Stereographic	Approximately 24 km resolution	CD – Rom # 1	Binary
DEM	GRIDDED DEM	Conversion And Analysis	UTM NAD83 Zone 10	25 m resolution	CD – Rom # 1	Binary, Header – MS Excel
BC Hydro Basins	Polygon	Use of Cheakamus Basin and it's elevation bands as mask area	Geographic	Unknown	CD – Rom # 1	Shapefile
DCP	Point	Mask point	UTM NAD83 Zone 10	Unknown	CD – Rom # 1	MS Excel

6.2 Study Area

The project area was the drainage basin for the Daisy Lake Reservoir (Cheakamus basin) because of most previous R&D GIS work had been done on this basin. It is located in the Coast Mountains of Southwestern British Columbia about 30 km north of Squamish. It's drainage area is 721 km². Elevations range from 342m to 2677m above sea level.

The basin intercepts warm Pacific air masses and experiences high annual precipitation. The orientation of the western valley containing Cheakamus Lake may result in lower precipitation compared to the main valley, which is aligned with Pacific frontal storms that move inland from the southwest.

A subset from Quadrangle 92 – 92F, 92G, 92H, 92J, 92K and 92O Gridded DEM maps covered the area of 97954 square kilometers.

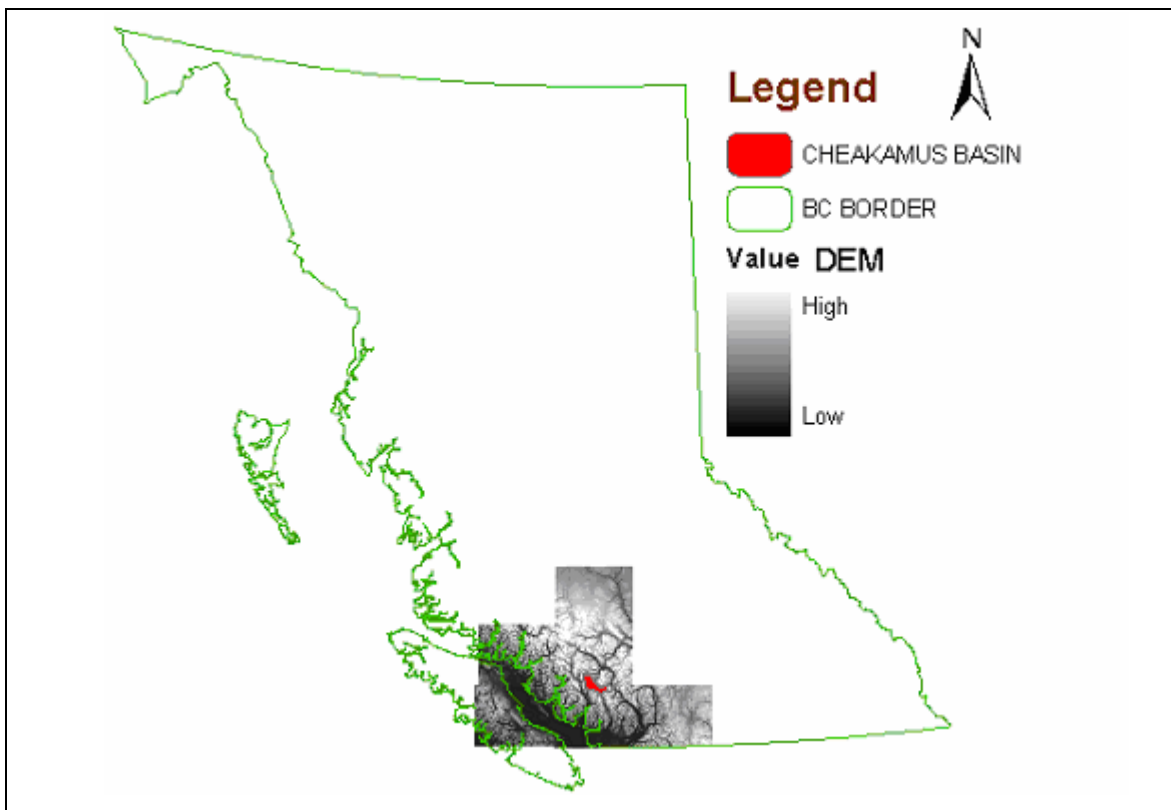


Figure 1. Location of the study area.

GRIB point coverage was created for an area with the following geographic extent: N 49° - N 51° latitude and W 121° - W 125° longitude (123 points).

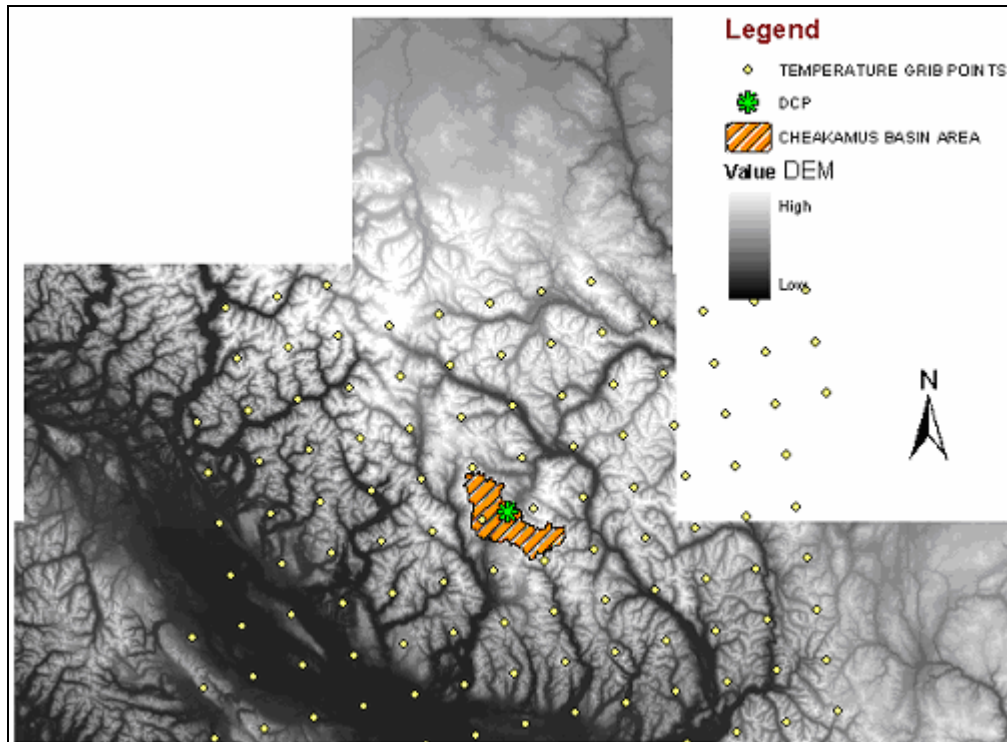


Figure 2. Location of the study area showing GRIB points, DEM and DCP.

7. Project Methodology

7.1. Data Input, Data Manipulation, Algorithms

7.1.1 General Methodology.

For every daily dataset we have

- assembled base layers
- recorded temperatures

Base layers were: DEM, Aspect and Slope grids, temperature grids (one of each, interpolated using IDW, Spline, Kriging and predicted with Multiple Regression)

Analysis – all derived from this date GRIB file), Cheakamus basin shape file, eight Cheakamus elevation bands files, DCP coverage.

Average temperatures were recorded for the whole basin for every interpolated grid and for the whole basin and for each elevation band for predicted grid.

Temperatures were also recorded @ the DCP location for every grid.

7.1.2 DEM, Aspect and Slope.

In order to use Gridded DEM files in ArcGIS we had to convert it to Arc Grid format using the methodology described by Susan Westmacoff

<http://home.gdbc.gov.bc.ca/products/griddem-ARCIInfo.htm>.

The conversion steps are:

- reorganize the header file
- rename the image file from “*.grd” to “*.bsq”
- run the IMAGEGRID command from the ARC prompt
- the resulting grid doesn't yet have the right values - it needs the CNVRTIMAGE.AML to be run over it. (This macro is available at the same

web site)

Further on data was resampled from 25 to 100 meters resolution and merged into one dataset. MOSAIC function from the ArcInfo GRID geoprocessing program was used:

Example: **Grid: temp = mosaic (92f, 92g, 92h, 92j, 92k, 92o)**

The same function could be used with the Spatial Analyst extension in ArcMap.

Aspect and Slope grids were created from final DEM using standard Surface Analysis functions of Spatial Analyst extension in ArcMap.

7.1.3 Cheakamus basin and DCP.

The single shapefile that contained all elevation bands of the Cheakamus basin was derived from a larger BCH Basins dataset. It's projection was changed from Geographic to UTM NAD 1983 Zone 10 using ArcToolbox Project Wizard for shapefiles and geodatabases. Then separate shapefiles were created for each of

eight basin elevation bands using ArcMap Export Data functionality on selected features.

Since there is only one DCP within the Cheakamus basin we have created one point coverage using ArcToolbox “Generate to Coverage” Wizard manually typing x and y coordinates of that station. Then UTM NAD 1983 Zone 10 projection was defined for that coverage with the help of ArcToolbox.

7.1.4 GRIB data.

It was discovered that though GRIB data is widely used for many years in non-GIS applications we could not find any recommendations about importing it into ArcGIS. The only commercial software called Network FileServer was found through ESRI web site

<http://gis.esri.com/library/userconf/proc00/professional/papers/PAP334/p334.htm>

that automatically converts the WMO forecast GRIB format grids into ESRI grid format did not appear to be available.

We needed to find the ways to convert this data into ESRI Grid format.

This problem contained two parts:

- converting files from binary to ASCII format
- converting from ASCII to ESRI grid

Wgrib program was used for solving the first part of the problem. We used Windows version of Wgrib to translate all project GRIB files, manually running commands from the Command Prompt.

Example: C:\work\>wgrib LR60km.grib -V this provides only DOS output with the brief description of the file content (not saved anywhere, copied here only for demonstration)

```
rec 1:0:date 2003031900 TMP kpds5=11 kpds6=105 kpds7=2 levels=(0,2) grid=255
2m above gnd anl:TMP=Temp. [K] timerange 10 P1 0 P2 0 TimeU 1 nx 135 ny 95 GD
S grid 5 num_in_ave 0 missing 0 center 54 subcenter 0 process 36 Table 2 polar
stereo: Lat1 27.203000 Long1 -135.213000 Orient 249.000000 north pole (135 x 95
) Dx 60000 Dy 60000 scan 64 min/max data 232.646 301.846 num bits 10 BDS_Ref 2
326.46 DecScale 1 BinScale 0
```

Figure 3. Reading the GRIB file

Example: `D:\work\GRIB>wgrib HR24km.grib -d 1 -text` this creates some unimportant DOS output and a dump file.

Contents of the dump file:

```
313 249          - number of rows and columns
291.146          }
290.746          } - values in sequence, in this case temperatures [K°].
290.446          }
290.246          }
.....
```

Images below are High Resolution Regional grid matrix and ESRI Grid, displayed in ArcMap that was created by ASCII GRID command over a slightly modified dump file. However we could not use it for analysis – there was a problem with georeferencing of that dataset. The reason is that Polar-Stereographic grid points are not equally spaced as ASCII GRID format assumes. Some other approach for creating grids had to be found.

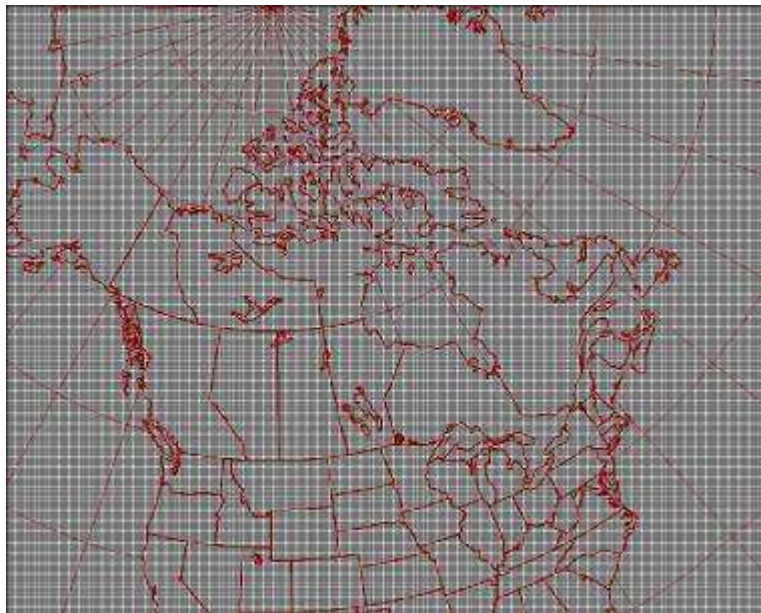


Figure 4. Regional grid matrix.

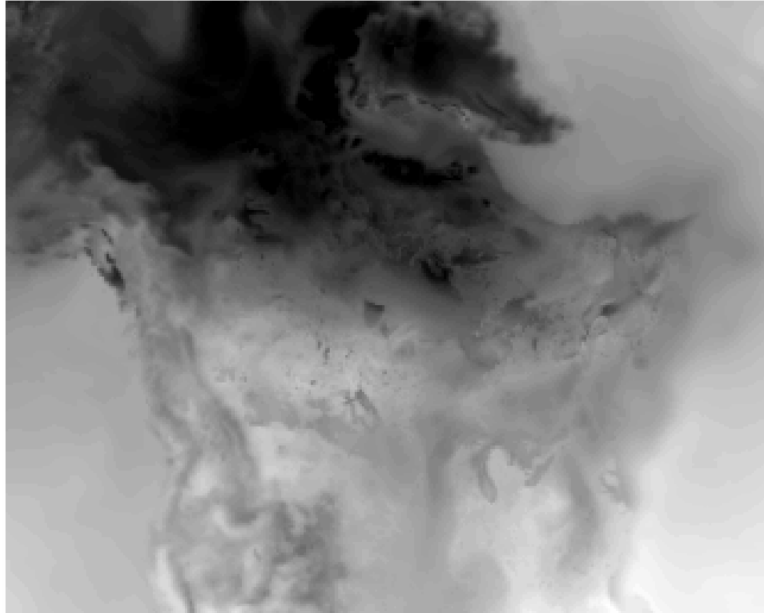


Figure 5. First approach regional temperature grid

It was decided that we need to create a point coverage first (using “Generate To Coverage” Wizard of ArcToolbox) and then interpolate point temperature values to grid.

Next step was to merge daily temperatures of the dump file with corresponding geographic coordinates. For this purpose a file formatting program was written.

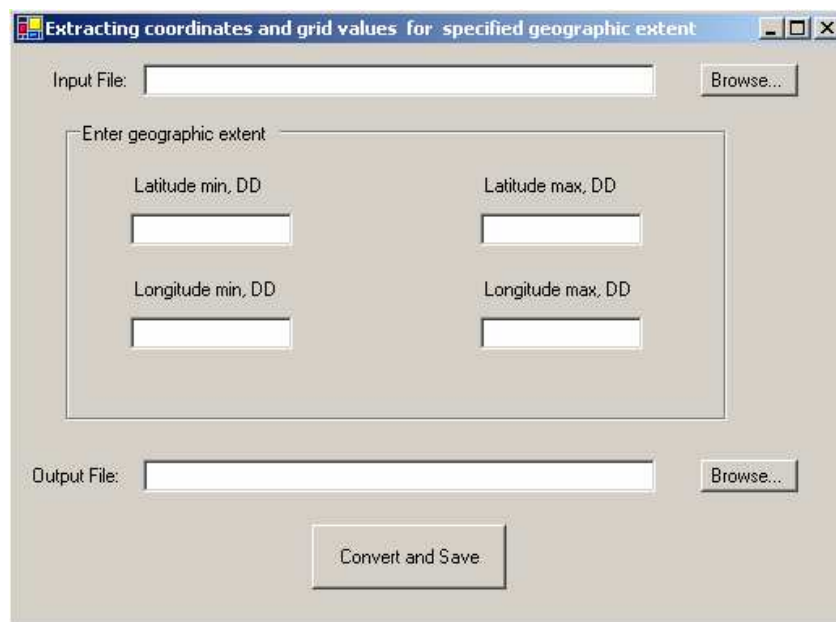


Figure 6. Graphical User Interface of the text formatting program.

The program source code is provided in the Appendices.

This program is reading dump file into an array, then reads the file with geographic coordinates into another array, then merges them together and creates a subset for the desired geographic extent in a new text file converting temperature values from [K°] to [C°]. This file is ready to use with “Generate To Coverage” Wizard.

The image below demonstrates point coverage for the whole region and for the Quadrangle 92 area (N 48° - N 52° latitude and W 120° - W 128° longitude) in geographic projection.

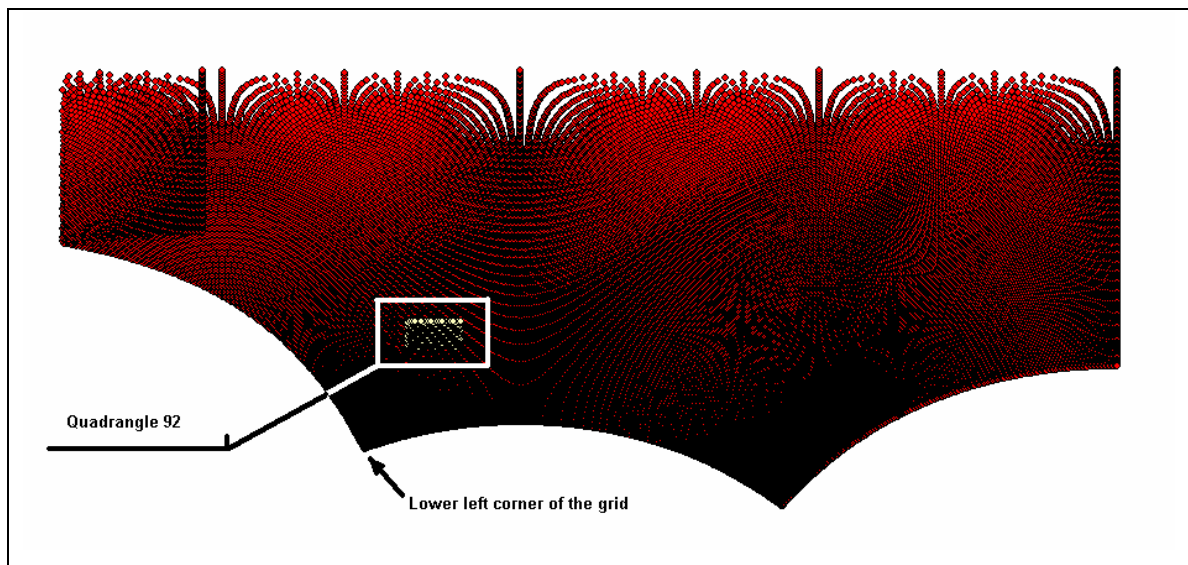


Figure 7. Point Coverage containing Regional High Resolution grid points.

Next step is to define this new coverage projection as Geographic and reproject it to UTM NAD 1983 Zone 10. We used ArcToolbox Define Projection Wizard for coverages and grids and Project Wizard for coverages.

The topology still has to be built for the newly created coverage so we use ArcToolbox Build command.

Finally we used` ArcMap to add a new field to the Feature Attribute Table that will hold the temperature values and calculate values for it copying them from the

“\$angle” field which was generated by “Generate To Coverage” Wizard. The “\$angle” field contains temperature values from the input text file.

In general the conversion process could be presented by the following algorithm:

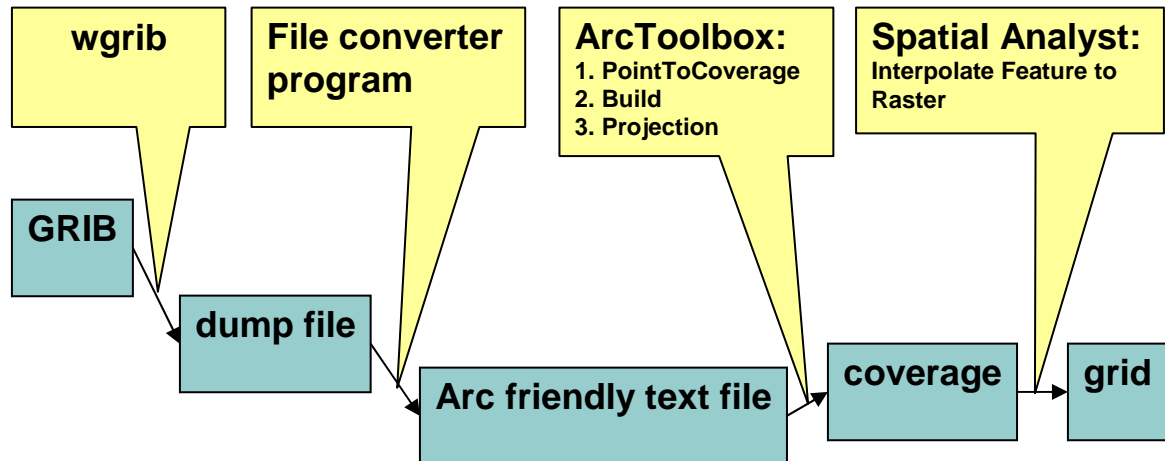


Figure 8. Conversion process algorithm.

7.1.5 Interpolated Grids.

After completing creation of the 30 temperature GRIB point coverages we could start interpolating them into grids. IDW (Inverse Distance Weighted), Spline and Kriging methods were used. Common to all three of them were following parameters: 100 meters cell size and temperature value as Z value.

Inverse Distance Weighted interpolation estimates cell values by averaging the values of sample data points in the surrounding of each cell. The closer a point is to the center of the cell being estimated the more influence or weight it has in the averaging process. The variable decreases in influence with distance from its sampled location. A higher Power option puts more emphasis on the nearest points, creating a surface that has more detail but is less smooth. A lower power gives more influence to surrounding points that are farther away, creating a smoother surface. For this project we used a common value 2. This is default value by the way. Also we used Search radius type “Variable” which define the

search radius for each interpolate cell, depending on how far it has stretch to reach the specified number of input points.

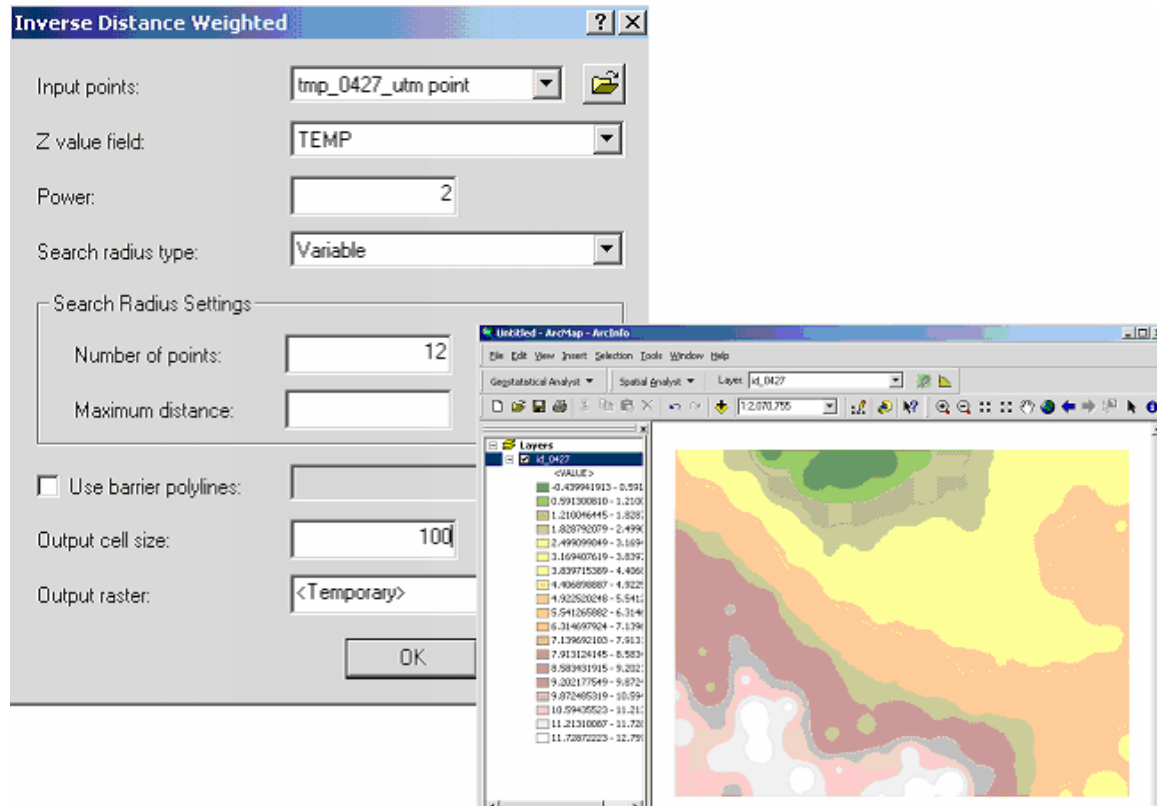


Figure 9. Creating a temperature grids using IDW interpolation

Spline interpolation estimates values using a mathematical function that minimizes overall surface curvature, resulting in a smooth surface that passes exactly through the input points. It fits a mathematical function to a specified number of nearest input points while passing through the sample points. Option Spline type: “Tension” – the higher the weight, the coarser the surface and the more the values conform to the range of sample data. Weight values must be greater than or equal to zero.

“Regularized” – The higher the “weight”, the surface is smoother. Weights between 0 and 5 are suitable. In this project we used weight value of 0.1.

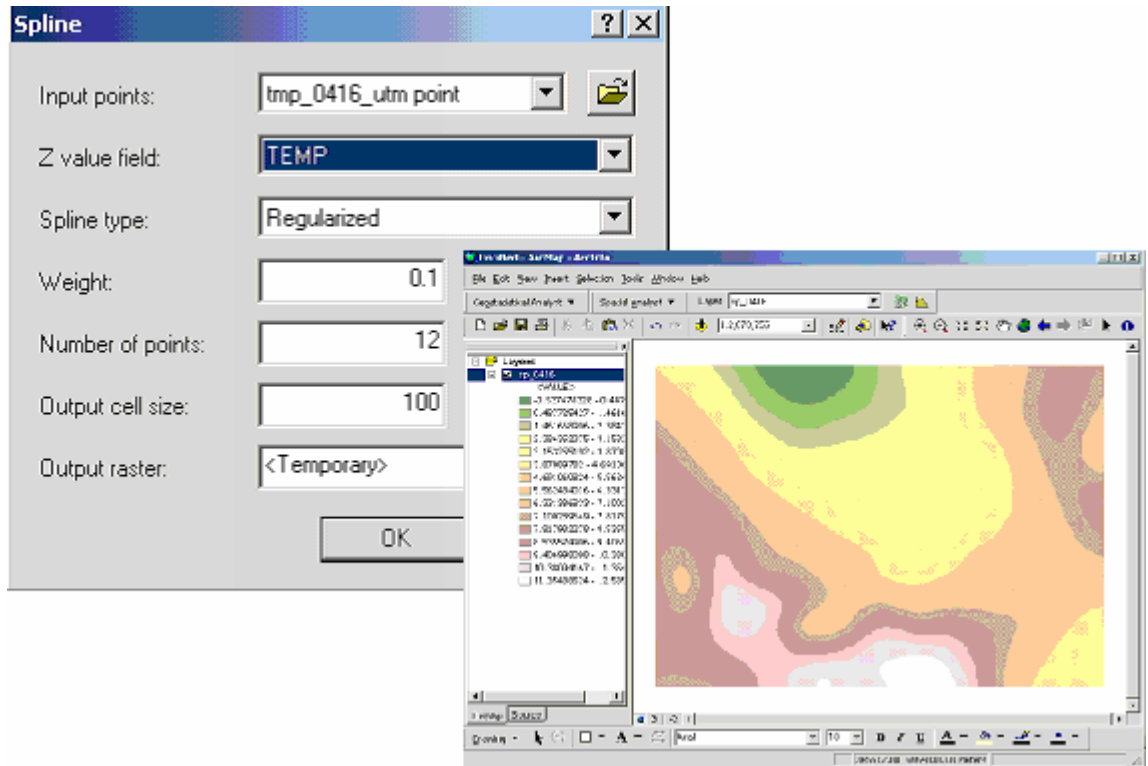


Figure 10. Creating a temperature grids using Spline interpolation

Kriging is an advanced geostatistical procedure that generates an estimated surface from a scattered set of points with z values. Unlike the other interpolation methods supported by ARC/INFO, Kriging involves an interactive investigation of the spatial behavior of the phenomenon represented by the z values before the user selects the best estimation method for generating the output surface.

Because the appropriateness of our data for modeling with this technique was not determined, for this project we simply used the default parameters:

“Ordinary” Kriging method with “Spherical” Semivariogram mode and Search radius type as “Variable”.

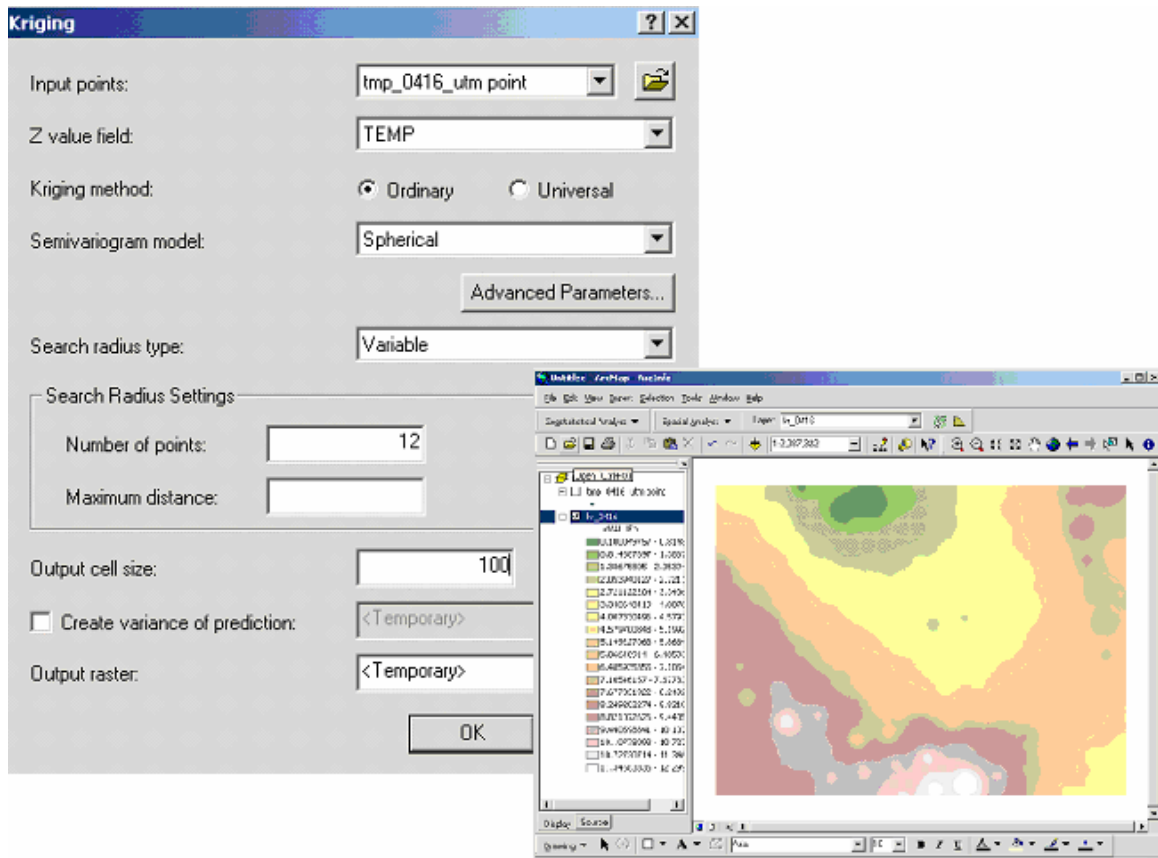


Figure 11. Creating a temperature grids using Kriging interpolation

A simple macro named “inter_list.aml” was written to eliminate manual work when processing numerous datasets. This AML will interpolate list of coverages to list of rasters using the **&do &list** structure and three different methods of interpolation. This macro text can be found in the Appendices.

7.1.6 Multiple Regression Analysis

Accurate climate data only exist for point locations, the meteorological stations, as a result of which values at any other point in the terrain must be inferred from neighboring stations or from relationships with other variables.

Many studies model the spatial distribution of a climate variable using interpolation methods. These techniques can obtain satisfactory results from limited data, based mainly on the geographic situation of the sampling points, on

the topological relationships between these points, and on the value of the variable to be measured. However interpolation methods only consider spatial relationships among sampling points and do not take into account other properties of the landscape. (Marquínez 2003)

Multiple regression analysis was used to examine the relationship between a dependent variable (temperature) which value is known at a number of locations (GRIB data points) and a set of independent variables (elevation, slope, aspect) which values are also known for those locations.

Multiple linear regressions would have to be calculated for each day dataset however for this study it was determined to be sufficient just to establish the process so only six datasets were calculated: a sample files for dates from April 1 to April 6 2003 were created using Grid function SAMPLE over GRIB points, DEM Aspect and Slope grids.

*Example: Grid: **smpl_1_04 = sample (point_1_04, elevation, aspect, slope)***

Grid REGRESSION command was used to calculate corresponding coefficients for the independent variables.

*Example: Grid: **regression sampl_104***

Example of brief output of the REGRESSION command:

coef #	coef
0	7.013
1	-0.003
2	-0.029
3	-0.001

To create a grid of predicted values for the dependent variable at each location using these coefficients (which produces a friction or preference surface), the following formula was used:

$$\text{prediction} = a_0 + a_1x_1 + a_2x_2 + a_3x_3 + \dots$$

We have masked DEM, Aspect and Slope grids with Cheakamus basin shapefile so that those subsets could be used for calculating predicted grid.

The calculation was done with ArcMap Spatial Analyst Raster calculator.

Predicted grids were created for all six prepared datasets from April 1 to April 6, 2003.

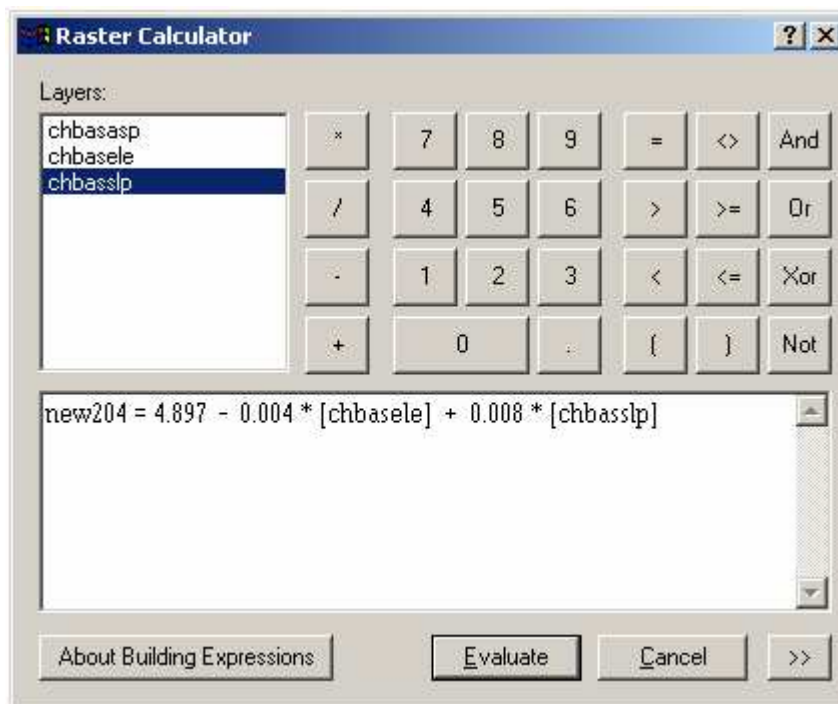


Figure 12. Screenshot of Spatial Analyst Raster Calculator

Average temperatures for the whole basin and for each elevation band were then recorded for each date predicted grid using ArcMap Statistics functionality.

Temperature values at the DCP location were also noted with the help of Identity function of ArcMap.

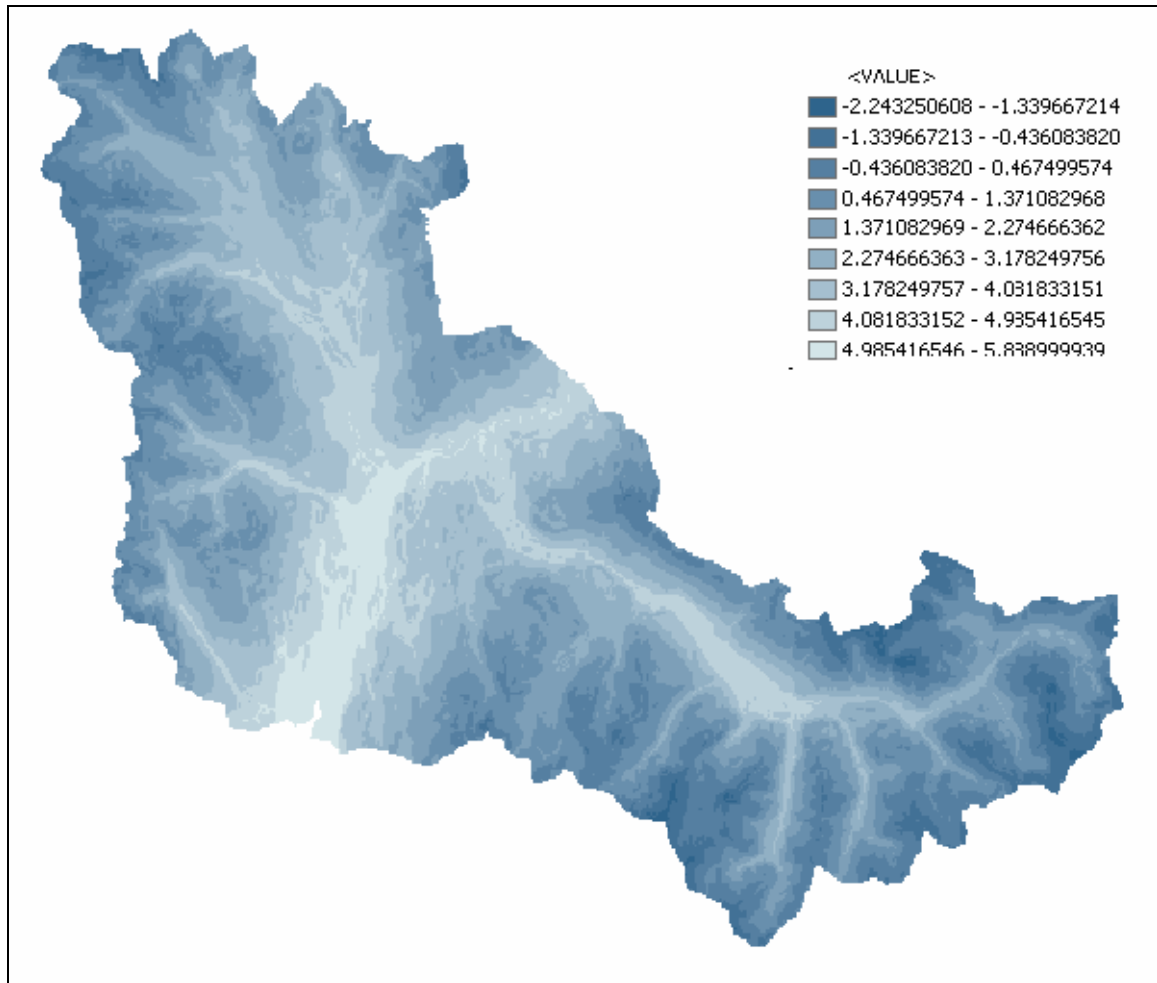


Figure 13. Screenshot of predicted grid. Date: April1, 2003

7.2 Tools and Languages

Data management, manipulation and analysis were completed using ESRI's ArcGIS 8.2: ArcCatalog, ArcMap, Spatial Analyst Extension, ArcToolbox and ArcInfo Workstation.

Project reports and presentations were completed using Microsoft Office XP. File formatting program was written in Visual Basic.NET.

Microsoft Internet Explorer version 6.0 was used for downloading data from the Internet. All software used for this project is licensed for BCIT to be used for educational purposes. These programs are installed on IMB PC's in GIS labs 2980 and 2635. This final report was printed on the BCIT LaserJet printer.

7.3 Project Management Techniques

The following Project Management Techniques were implemented for this project:

- - project monitoring and control
- - status reporting
- - performance analysis

Project status meetings were held regularly every week both with project sponsor and project supervisor.

Team members were fully aware of classic development mistakes and did their best to avoid them. For instance we could feel the influence of the phenomenon called Feature Creep when planning the resulting datasets, but with the help of project sponsor and project supervisor we've managed to stay focused on the most important aspects of the project.

Facilitation tools such as Action Plan, Brainstorming and Flowcharts were often used.

Our favorites from Software Development Best Practices were:

- -Daily Build and Smoke Test
- -Staged Delivery
- -Throwaway Prototyping
- -Voluntary Overtime

8. Data Management / Software Management

8.1 Back Up Strategy

This project Back Up Strategy was to store all current and dated project data on Rewritable CDs and only the current data in the student UNIX folder where it was copied with FTP over the Internet.

8.2 Naming Conventions and Version Management

Standard GIS terminology and naming conventions were used for this project. For a small part of this project which was required writing a program software versioning allowed us to keep track of various versions of the code. This made it easier to debug the program.

8.3 Diagrams / Flowcharts

Due to the nature of this project Diagrams and Flowcharts were mainly substituted with maps and screenshots that helped to better visualize project issues.

9. Project Results, Recommendations

CMC meteorological data has recently become a valuable source of data for hydrology modeling and we have successfully imported it into GIS.

The resolution of the regional temperature grid is not high enough to determine horizontal distribution within the area of one catchment basin, however basin average and @DCP temperatures could still be used for further analysis and modeling. Tabular data is prepared.

The methodology for creating temperature rasters predicted with Multiple Regression Analysis of topological factors was established and results were obtained for first six datasets.

Established procedure could be now used for different basins and different meteorological parameters.

If further usage of CMC GRIB data is considered CMC recommends to access the data by writing a script that calls a web file-transfer utility, such as "wget" – this will eliminate manual downloading process.

In future it may be a good idea to rewrite file formatting utility in a VBA customization module of ArcMap, so that one application will be used for every step of the process. Note that currently the existing program is changing point values to convert them from [K°] to [C°]. Therefore it needs to be modified if used on another types of data, such as precipitation for example.

For further studies predicted rasters calculation could be automated with specially written AMLs.

10. Conclusions

The project started on January 6 and ended on May 18. Planned tasks were completed after 493 hours of technical work and 216 hours of management work. This report provides an overview of the data, objectives, methodology and results of this work.

This project has demonstrated good potential of using GIS tools for deriving data for hydrology modeling.

11. References

Jorge Marquínez, Javier Lastra and Pilar García, *Estimation models for precipitation in mountainous regions: the use of GIS and multivariate analysis* Journal of Hydrology, **270** (2003), 1–11.

Quick, M. 1995. *UBC Watershed Model Manual, version 4.0*. University of British Columbia, Mountain Hydrology Group, Department of Civil Engineering.

Our Business 2003. Company web site,
<http://www.bchydro.com/info/index/index3192.html>

12. Appendices

12.1 Final time accounting table

	TASK	A	B	C	D	E	Dzenita		Stanislav	
		Originally Estimated ,hrs	Revised Estimate, hrs	Hours to date	% complete (C/B)	Estimate D +/- (B-A)	HRS this rpt	HRS to date	HRS this rpt	HRS to date
1.0	Project Design	20	20	20	100.00	0.00	0	3	0	17
2.0	Data Preparation									
2.1	Data download and ingest (GRIB)	64	30	30	100.00	-34.00	0	0	0	30
2.2	Build database	16	16	16	100.00	0.00	8	8	0	8
2.3	Analyze data	16	46	46	100.00	30.00	8	38	0	8
2.4	Prepare DEM data	32	51	51	100.00	19.00	0	24	0	27
2.5	Setup of basins, elevation bands, slope/aspect/elevation/curvature layers, weather station locations	32	21	21	100.00	-11.00	4	13	0	8
2.6	Prepare GRIB data	0	163	163	100.00	163.00	0	64	0	99
3.0	Software									
3.1	Interface design	8	0	0	0.00	-8.00	0	0	0	0
3.2	Write code	16	32	32	100.00	16.00	0	0	0	32
3.3	Debug code	16	22	22	100.00	6.00	0	0	0	22
3.4	Review geospatial interpolation and downscaling techniques (modeling, kriging, spline, etc.)	40	20	20	100.00	-20.00	0	12	0	8
3.5	Select several techniques and code them	40	0	0	0.00	-40.00	0	0	0	0
4.0	Data Analysis									
4.1	Program output (run the model)	36	0	0	0.00	-36.00	0	0	0	0
4.2	Analyse the output / testing	36	58	58	100.00	22.00	2	34	8	24
4.3	Prepare data output for further analysis and prepare stats. (comparison with current assumptions made by the UBCWM)	48	14	14	100.00	-34.00	2	12	0	2
5.0	Project Management									
5.1	Meeting with supervisor	20	18	18	100.00	-2.00	1	9	1	9
5.2	Project weekly reports	24	22	22	100.00	-2.00	0	11	0	11
5.3	Meeting with project sponsor	20	32	32	100.00	12.00	2	13	2	19
5.4	Final written report	32	76	76	100.00	44.00	44	44	32	32
5.5	Final presentation	20	34	34	100.00	14.00	18	18	16	16
5.6	Cartography workshop	16	4	4	100.00	-12.00	0	2	0	2
5.7	Public Display	10	0	0	0.00	-10.00	0	0	0	0
5.8	Cartographic Poster	16	16	16	100.00	0.00	0	8	0	8
5.9	Data/Software Management	20	2	2	100.00	-18.00	0	1	0	1
5.10	GIS Conference Participation	0	12	12	100.00	12.00	0	2	0	10
	TOTAL	598	709	709		111.00	89	316	59	393

12.2 Program Documentation Section

Resulting Temperatures

IDW	Kriging		Spline			Observed	
AVERAGE TEMPERATURE Temp °C	DCP - CHEAKAMUS Temp °C	AVERAGE TEMPERATURE Temp °C	DCP - CHEAKAMUS Temp °C	AVERAGE TEMPERATURE Temp °C	DCP - CHEAKAMUS Temp °C	Predicted at DCP Temp °C	Upper Cheakamus DCP Temp °C
3.3	3.3	3.3	3.3	3.2	3.2		2.9
-1.0	-1.1	-1.2	-1.2	-1.2	-1.2		2.0
1.3	1.2	1.2	1.1	1.1	1.1		2.5
0.1	0.1	0.0	0.0	0.0	0.0		3.0
2.4	2.4	2.4	2.3	2.4	2.3		5.4
1.5	1.5	1.4	1.4	1.4	1.4	4.0	5.4
1.5	1.5	-2.3	-2.4	-2.4	-2.4	2.2	2.0
-2.2	-2.2	-1.2	-1.3	-1.4	-1.5	1.9	2.6
-0.7	-0.7	-0.8	-0.8	-0.8	-0.8	2.4	0.1
-2.4	-2.4	-2.5	-2.5	-2.5	-2.5	3.0	0.1
1.0	1.0	0.9	0.9	0.9	0.9	1.5	3.6
0.9	0.9	0.8	0.8	0.7	0.8		-0.2
4.1	4.0	4.0	4.0	3.9	4.0		3.8
1.8	1.8	1.7	1.7	1.7	1.7		2.8
4.1	4.0	3.9	3.8	3.3	3.8		6.1
4.2	4.2	4.1	4.1	4.1	4.0		5.1
3.3	3.2	3.1	3.1	3.0	3.0		9.2
1.4	1.4	1.3	1.3	1.3	1.3		1.8
2.4	2.3	2.3	2.1	2.2	2.0		4.3
3.3	3.2	3.3	3.2	3.1	2.8		5.0
1.2	1.1	1.1	1.0	1.1	0.9		3.2
2.9	2.9	2.8	2.7	2.7	2.7		2.5
6.8	6.8	6.8	6.8	6.7	6.8		9.3
6.2	6.2	6.1	6.0	6.0	5.9		11.1
2.6	2.6	2.4	2.4	2.4	2.3		4.0
0.9	1.0	0.8	0.8	0.8	0.7		1.1
3.6	3.5	3.4	3.3	3.4	3.3		9.0
4.1	4.0	4.0	3.8	3.9	3.7		7.8
4.3	4.3	4.1	4.1	4.1	4.1		6.4
9.1	8.9	9.0	8.6	8.9	8.5		12.1

Listing of inter_list.aml

```
*****
```

```
/* program: inter_list.aml
/* purpose: interpolate list of coverages to list of rasters using the &do &list
structure
/* and three different methods of interpolation
/* note: empty folders named "ID","krig" and "spline" should be created
/* inside the workspace before running this AML.
```

```
grid
```

```
&do cover_i &list [listfile * -cover]
```

```
    ID\id_%cover_i% = idw (%cover_i%, temperature, #, #, sample, #, #, 100)
```

```
    krig\kr_%cover_i% = kriging (%cover_i%, temperature, #, GRID, #, #,
sample, #, #, 100)
```

```
    spline\sp_%cover_i% = spline (%cover_i%, temperature, REGULARIZED,
#, #, 100)
&end
```

```
q
```

```
&return
```

```
*****
```

Listing of file formatting program written in Visual Basic.NET

```
Option Strict On
```

```
Option Explicit On
```

```
'file formatting
```

```
'this utility program is designed to create a file, that is used as
'an input for ArcToolbox "Generate To Coverage" Wizard or
'ArcInfo "Generate" command, from the dump file (ASCII format)
'created by wGrib utility that reads binary CMC GRIB files,
'containing temperatures values for each point of regional grid.
```

```
Public Class frmFileIO
```

```
    'Global Variables
```

```
    Dim strLines() As String
```

```
    Dim strLineData As String
```

```
    Dim strRC(2) As String
```

```
    Dim strLD(4) As String
```

```
    Dim dblTemp As Double
```

```
    Private Sub File_In(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
btnBrowseIn.Click
```

```
'user clicked "Browse..." button next to input textbox
'show file open dialog
ofdIn.ShowDialog()
```

```
'assign returned file name to textbox
txtIn.Text = ofdIn.FileName
```

End Sub

```
Private Sub File_Out(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
btnBrowseOut.Click
```

```
'user clicked "Browse..." button next to output textbox
'show file save dialog
sfdOut.ShowDialog()
```

```
'assign returned file name to textbox
txtOut.Text = sfdOut.FileName
```

End Sub

```
Private Sub btnSave_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
btnSave.Click
```

```
'user clicked "Convert and Save" button
'Declairs a streamreader object to read the file
Dim srIn As IO.StreamReader
Dim srIn2 As IO.StreamReader
'Declairs stream writer object for output
Dim srOut As IO.StreamWriter
Dim i, j As Integer
```

```
'open the file containing GRIB values
srIn = IO.File.OpenText(txtIn.Text)
```

```
strLineData = srIn.ReadLine 'reads the first line of that file
strRC = strLineData.Split(CChar(" ")) 'gets tokens from the string
```

```
If strRC.GetUpperBound(0) < 1 Then 'if less that two - wrong file - abort
    MsgBox("Please, make sure the dump file has number of rows and columns.")
    Exit Sub
End If
```

```
'the following condition checks if LAT/LONG user input is numeric
If Not IsNumeric(txtLatMin.Text) Or Not IsNumeric(txtLatMax.Text) Or Not
IsNumeric(txtLongMin.Text) Or Not IsNumeric(txtLongMax.Text) Then
    'user is prompted to check and confirm the input or process the whole dataset
    If MsgBox("You didn't specify bounding coordinates or you input is not correct. Do you want to
process values for the entire region?", MsgBoxStyle.YesNo, "Please check you input.") =
MsgBoxResult.No Then
        Exit Sub
    End If
End If
```

```
'open file for output
srOut = IO.File.CreateText(txtOut.Text)
```

'first line of the wGrib dump file always starts with 135 or 313 (low or high resolution grid)

```
Select Case CInt(strRC(0))
  Case 135
    'we dealing with low resolution dump
    'open the low resolution coordinates file
    srIn2 = IO.File.OpenText("LR.txt")
  Case 313
    'we dealing with high resolution dump
    'open the high resolution coordinates file
    srIn2 = IO.File.OpenText("HR.txt")
  Case Else
    MsgBox("Please, make sure the right dump file is selected.")
  Exit Sub
End Select

i = CInt(strRC(0))      'number of rows
j = i * CInt(strRC(1)) - 1 'number of columns
ReDim strLines(j)      'rediming the array to hold J number of elements

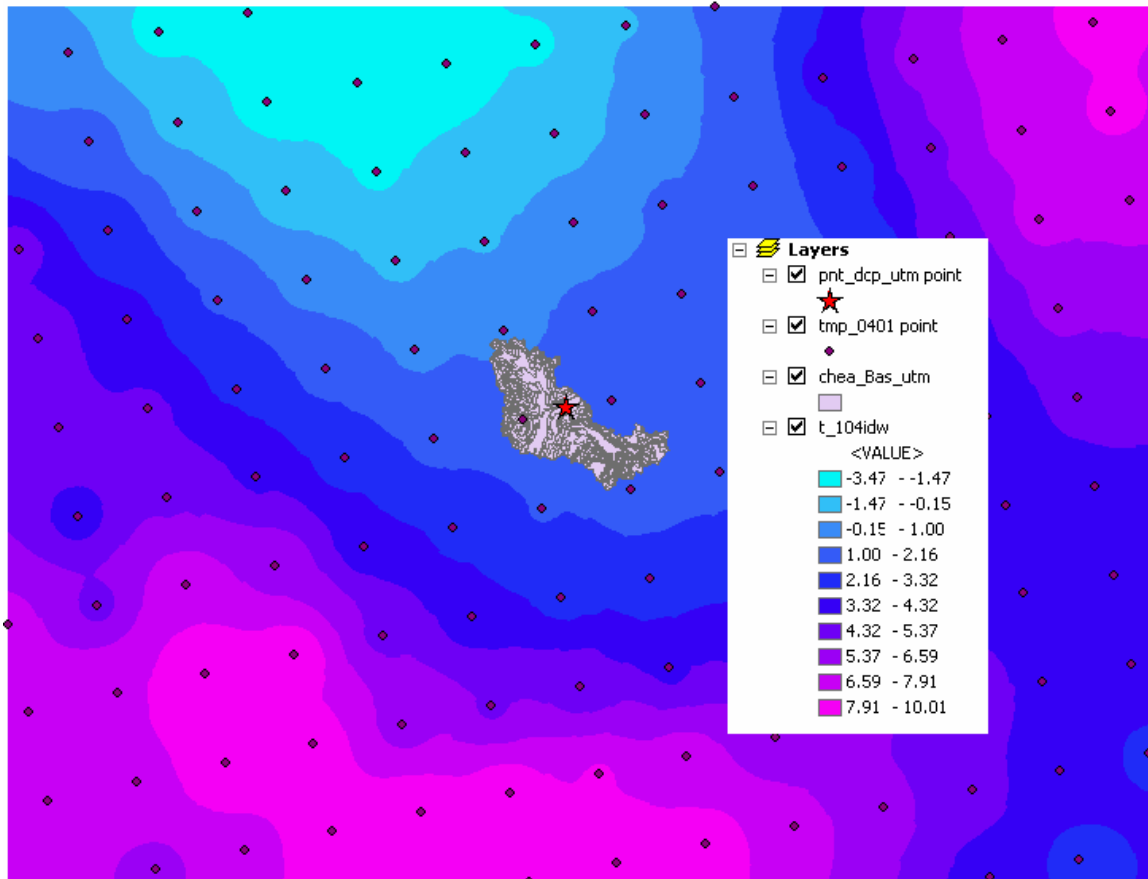
'in this loop every line of two files is read and blended together,
'populating string array strLines.
For i = 0 To j
  strLineData = srIn2.ReadLine 'reads the line with point ID and longitude, latitude
  strLD = strLineData.Split(CChar(",")) 'gets tokens from the string

  strLineData = srIn.ReadLine 'reads the dump file line with temperature value
  'intermediate variable gets value, converted to degrees Celsius
  dblTemp = Math.Round((CDBl(strLineData) - 273.15), 2) 'here is where values can be changed
  'final formatting of the string: ID, longitude, latitude, temperature in C.
  strLines(i) = strLD(0) & "," & strLD(1) & "," & strLD(2) & "," & CStr(dblTemp)

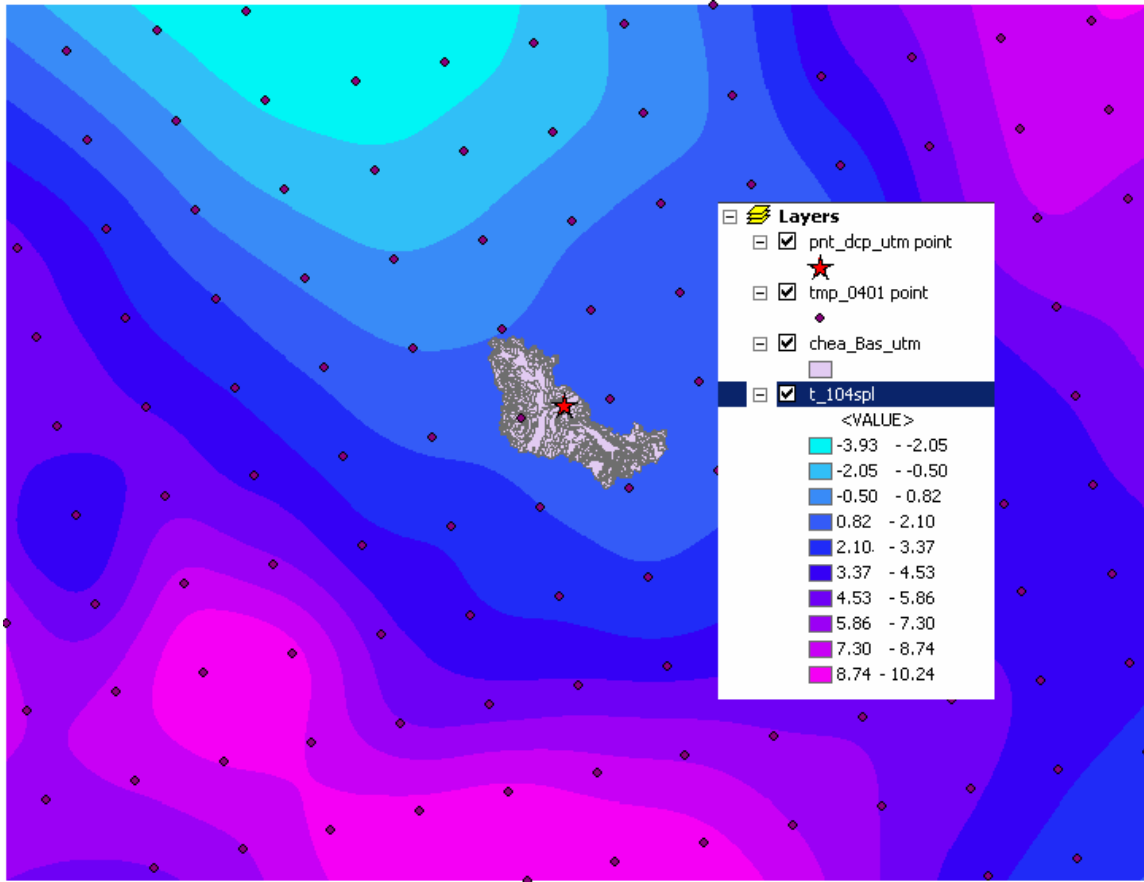
Next i
'now we loop through the array again
For i = 0 To j
  strLineData = strLines(i)
  strLD = strLineData.Split(CChar(","))

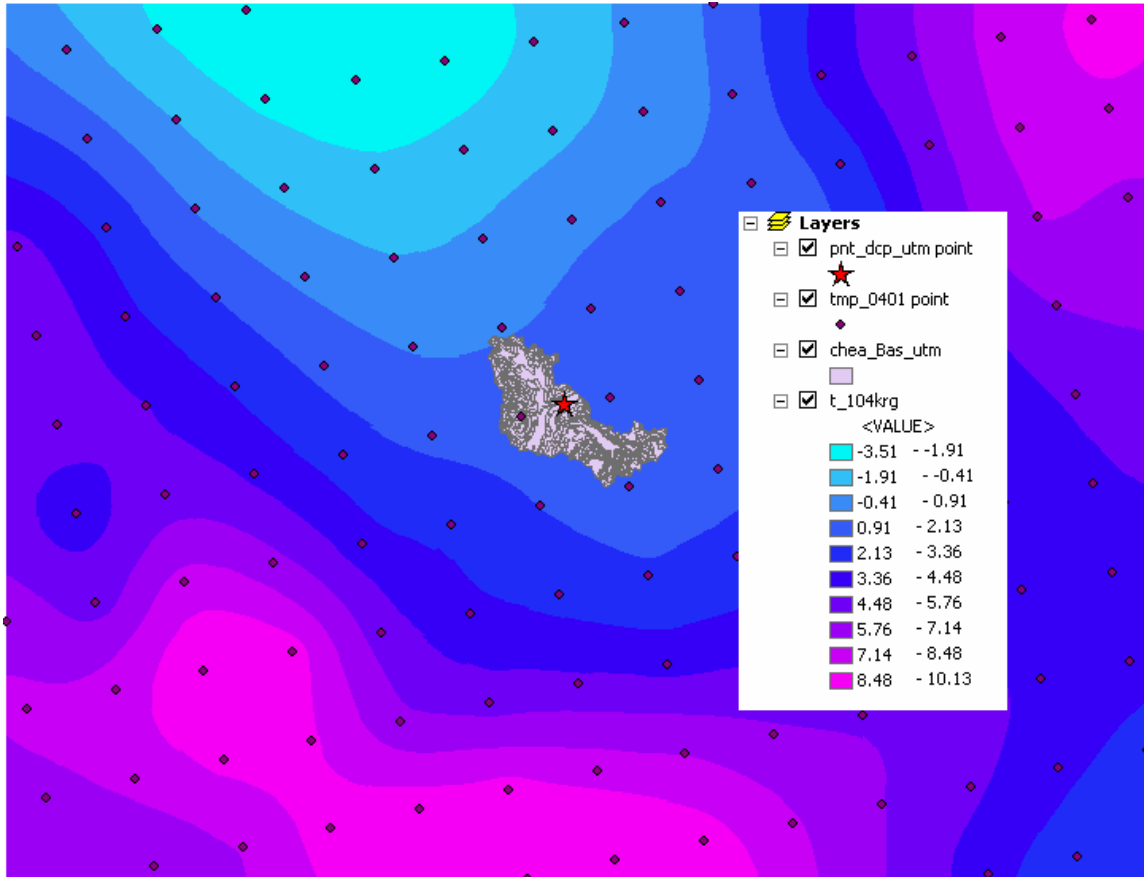
  'if the point is within the specified geographic extent
  'it is recorded into the file
  If CDBl(strLD(1)) >= CDBl(txtLongMin.Text) And CDBl(strLD(1)) <= CDBl(txtLongMax.Text)
Then
    If CDBl(strLD(2)) >= CDBl(txtLatMin.Text) And CDBl(strLD(2)) <= CDBl(txtLatMax.Text)
Then
      srOut.WriteLine(strLines(i))
    End If
  End If
Next i
'close the input files
srIn.Close()
srIn2.Close()
'close the output file
srOut.Close()
MsgBox("File is successefully created.")

End Sub
End Class
```

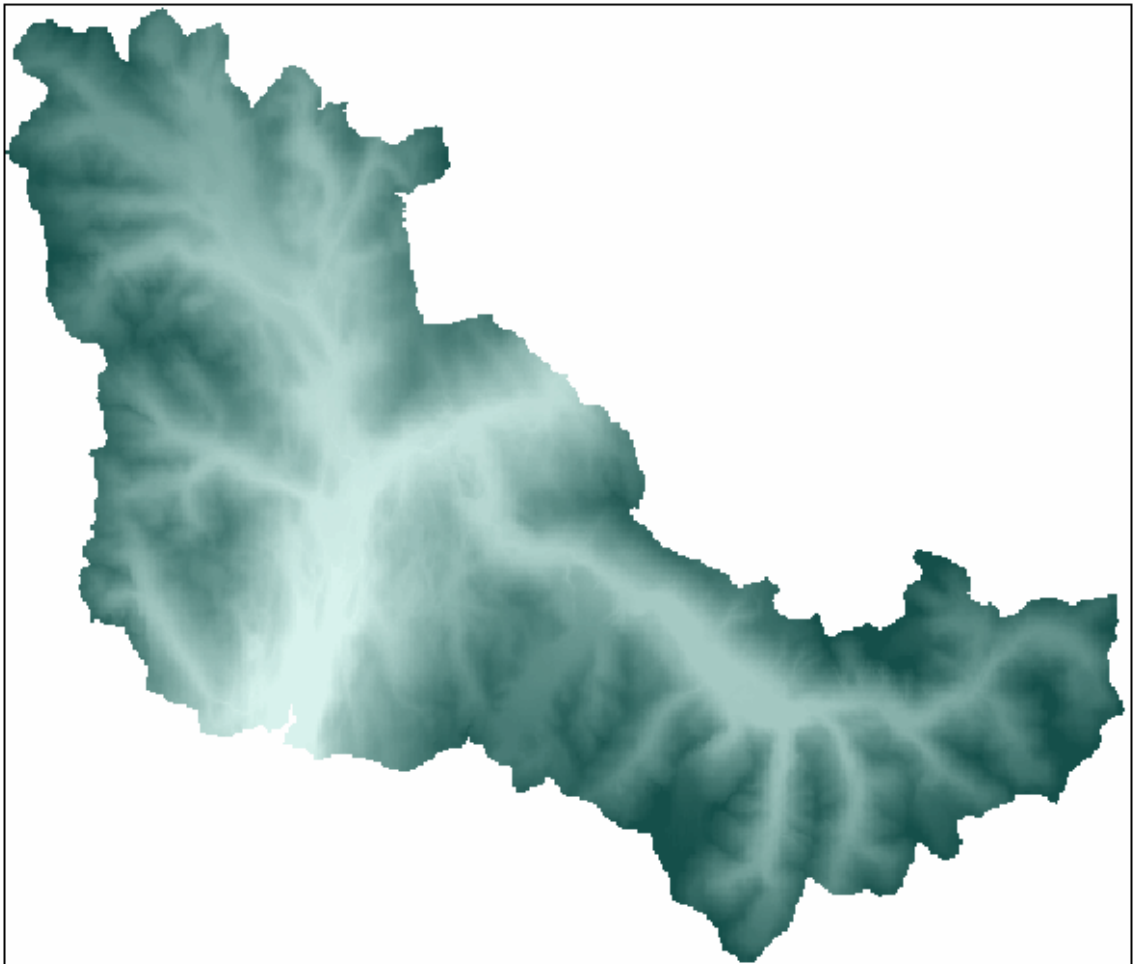
Cheakamus basin – DCP – GRIB points – interpolated temperatures grid (IDW)

Cheakamus basin – DCP – GRIB points – interpolated temperatures grid (Spline)

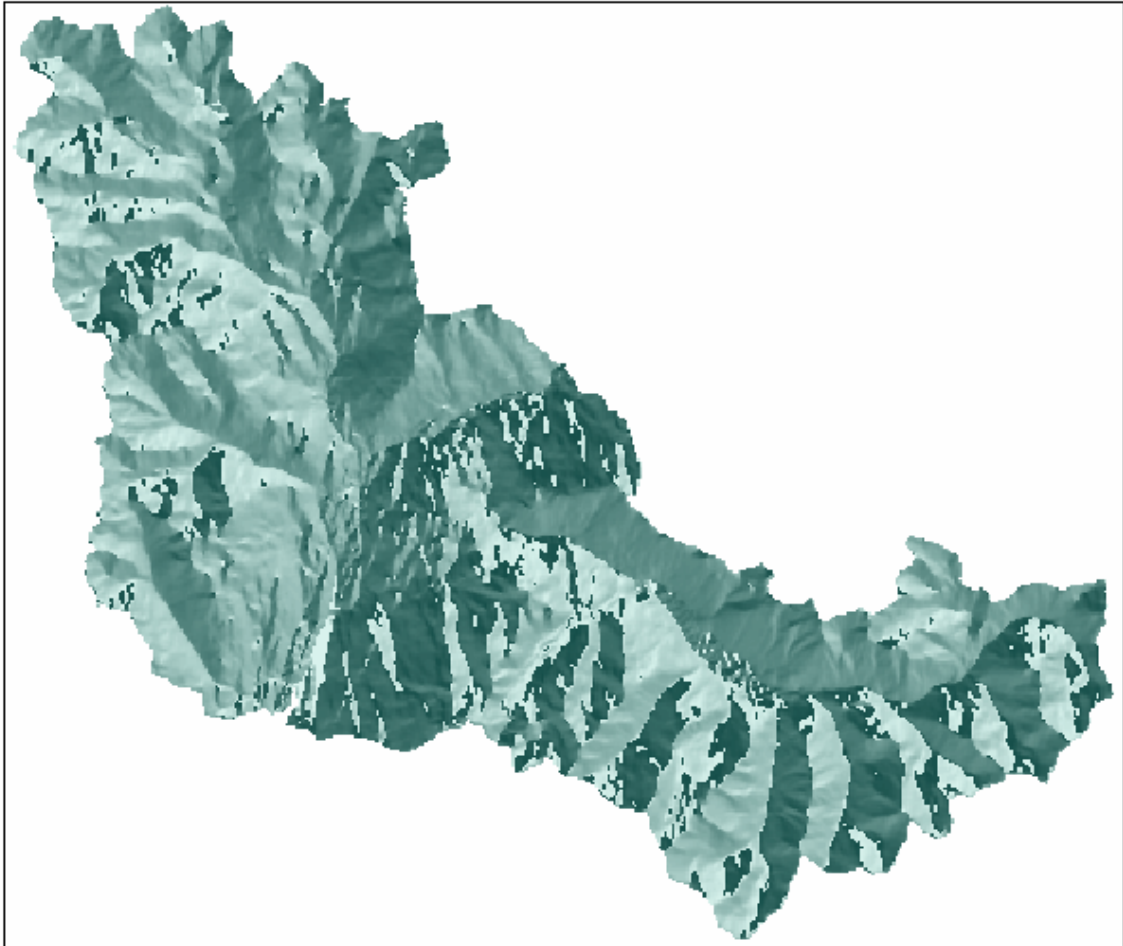


Cheakamus basin – DCP –GRIB points –interpolated temperatures grid (Kriging)

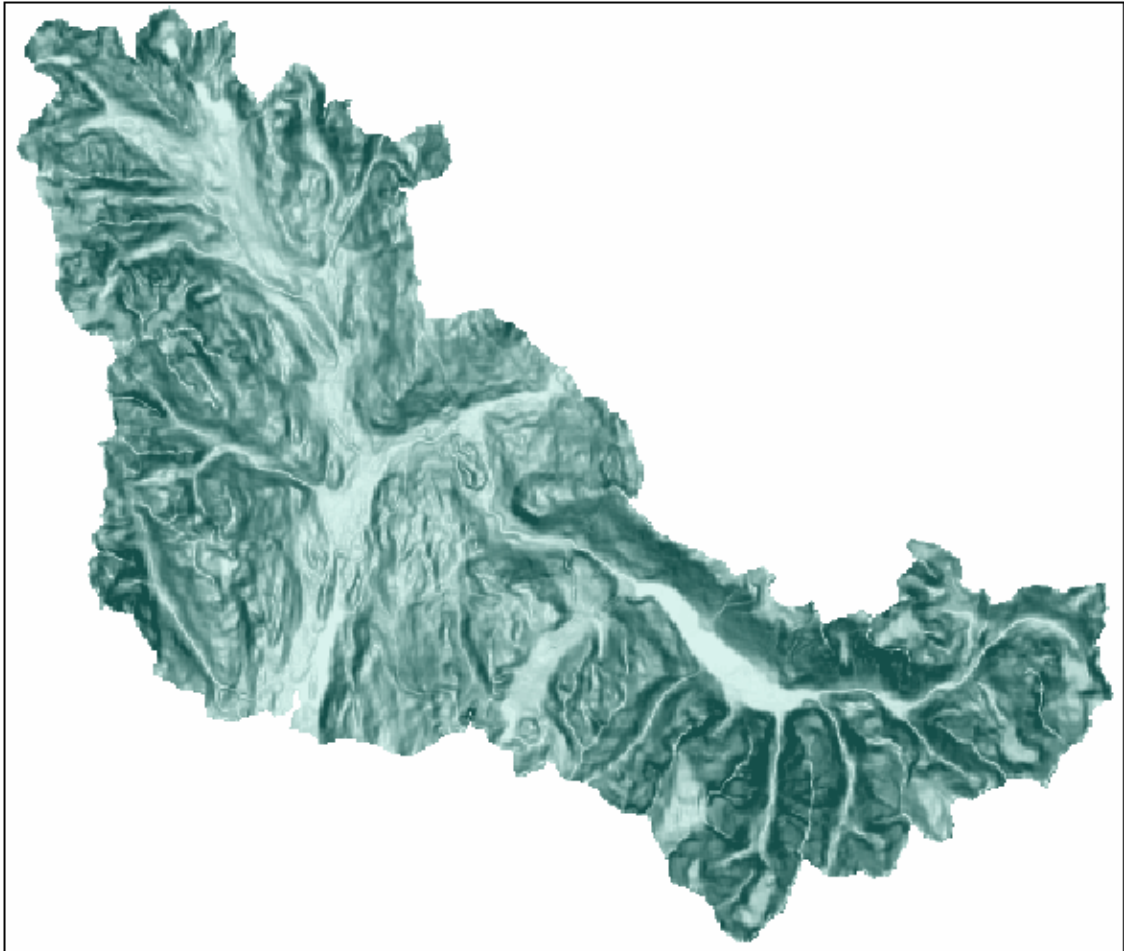
Cheakamus basin DEM



Cheakamus basin Aspect



Cheakamus basin Slope



Cheakamus basin predicted temperatures

date	Elevation Band Average Temperature °C								Basin Average Temperature °C
	band 1	band 2	band 3	band 4	band 5	band 6	band 7	band 8	
01/04/2003	5.2	4.4	3.6	2.7	1.9	1.2	0.4	-0.4	2.1
02/04/2003	3.1	2.3	1.3	0.4	-0.6	-1.6	-2.6	-3.8	-0.5
03/04/2003	3.0	2.0	0.8	-0.3	-1.5	-2.7	-3.9	-5.4	-1.4
04/04/2003	3.5	2.6	1.6	0.6	-0.4	-1.4	-2.3	-3.5	-0.2
05/04/2003	3.9	3.0	2.1	1.1	0.2	-0.8	-1.8	-3.0	0.3
06/04/2003	2.6	1.8	1.0	0.1	-0.7	-1.5	-2.2	-3.1	-0.5

12.3 List of the Primary Author for Each Section

	Section / Subsection	Stanislav	Dzenita
i	Title page	X	
ii	Abstract	X	
iii	Table of contents	X	X
1.	Introduction	X	
2.	The project statement		X
3.	Details of your project industry sponsor		X
3.1	General information		X
3.2	Contacts		X
4.	Project objectives	X	
4.1	Project objectives	X	
4.2	Project deliverables	X	

5.	Project background	X	X
5.1	UBC watershed model		X
5.2	Similar Projects	X	
6.	Project data	X	
6.1	Data sets and data dictionary	X	X
6.2	Study area	X	X
7.	Project methodology		X
7.1	Data input, Data manipulation		X
7.2	Resources used		X
7.3	Project management techniques		X
8.	Data management / software management	X	
8.1	Back up strategies	X	
8.2	Naming conventions and version management	X	
8.3	Diagrams / flow charts	X	
9.	Project results, recommendations	X	
10.	Conclusion	X	X
11.	References		X
12.	Appendices		X
12.1	Final time accounting table		X
12.2	List of the primary author for each section / subsection		X