The NATIONAL TRANSFORMATION

for converting between NAD27 and NAD83 in Canada

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Abstract

The National Transformation to convert coordinate data between the NAD27 and NAD83 reference systems in Canada is described in this paper. Background concerning many complex processes and the data used to model the differences between the two systems is provided, with some analysis of the accuracy. The resulting model is implemented by means of a simple, automated software package to enable most users to handle their own data conversion processing. Suitability of the National Transformation for various applications is also discussed.

Introduction

In May 1990, NAD83 (North American Datum of 1983) was proclaimed as the official geodetic reference system for all products of the federal Department of Energy, Mines and Resources. This marks the availability of coordinates in this new system for all major control survey networks in Canada, replacing the NAD27 (North American Datum of 1927) system which has been in use for the past 60 years.

To assist users in the transition to this new system, the Geodetic Survey Division, in cooperation with other federal and provincial government survey agencies, is providing users with a uniform technique to predict the the coordinate differences at points not coincident with established control survey stations. This technique will assist not only conventional users, such as mappers and thematic GIS data compilers, but also users concerned with offshore boundaries, such as the oil exploration industry.

This paper describes the concepts, software and data used to model the differences, and the simplified approach to implementing the model for distribution to users. The datum transformation is described first, followed by the much more complex task of modelling the distortion of the NAD27 network. An overview of the software developed specifically for this project is given, followed by a description of the data used and the results of some of the analyses. This information is provided mainly for background material.

The focus of the reader should be directed toward the latter part of the paper in which the implementation of the transformation by means of a grid shift table format is described. An accompanying document, "Program Descriptions and Users' Guide", gives more detail about the operation of this automated implementation.

The rationale for many of the decisions made during development is also presented to assist in understanding the form of the final product. Throughout the paper, the descriptions are interspersed with questions that have frequently been asked by prospective users during the development stages. This dialogue of question and response should deal with most concerns such as the decisions that were made, the suitability for a particular application, and where to obtain additional authoritative information.

Change in Reference Datum

• *What is the difference between the NAD27 and the NAD83 datums?*

The largest component of the change between NAD27 and NAD83 is due to the adoption of a new reference datum, which is geocentric and globally applicable. The reference ellipsoid for NAD83 is the GRS80 ellipsoid, the same as for the WGS84 reference datum used for the Global Positioning System (GPS). In fact, the NAD83 and WGS84 systems are essentially identical for all practical uses of geodetic control networks (Pinch, 1990; and DMA , 1987).

Because these two datums (NAD27 and NAD83) are specified differently (Pinch, 1990), a pragmatic approach was employed to determine the relationship between them based on the realization of each datum through the adjusted coordinates of selected control survey points. The only exact differences known *a priori* are the ellipsoid parameters for converting the XYZ spatial coordinates (of the Conventional Terrestrial System) to latitude and longitude.

To model this systematic change, which includes a shift in the origin at the centre of the earth of about 250 metres, a standard geodetic datum transformation (3-dimensional similarity transformation of 7 parameters) was tested. The determination of the parameters is based on comparisons of coordinate values for the precise Doppler network in Canada (~170 points), which was established coincident with existing primary control stations. This approach is not intended to produce a definitive relationship between the two datums, but rather, it is intended strictly for use with the National Transformation. It serves as a means of accounting for the large systematic datum shift and change of reference ellipsoid prior to modelling the distortions.

The testing cycle of programs - DATUM (determination of parameters), SCTRANS (application of parameters) and ESTPM (distortion modelling) - indicated that a simple set of 3 shifts worked as well as including the 3 rotation and one scale which make up the total complement of 7 parameters.

There are some rather obvious explanations for this - the most obvious of which is that there remain regional variations of ± 20 metres due to distortions in the NAD27 system.

Any improvement introduced by adding the extra four datum parameters is much smaller in magnitude than this 20 metre variation.

A second explanation is that the data used is limited to Canadian territory, which is concentrated on a small part of the globe, straddling the negative Y-axis. Thus, the Z-rotation parameter is very highly correlated to the X-shift, and the scale parameter is similarly correlated to the Y- and Z-shifts.

For these reasons, the added complexity was not considered justified in the context of the accuracy attainable, and the distortion model required to refine the transformation within this non-systematic ± 20 metres could adequately handle either approach.

• *Why can't I just apply the datum shift to my coordinates to get them into NAD83?*

The relationship between NAD27 and NAD83 is not explicitly known, due to the differences in the method of defining the two datums (Pinch, 1990). This, coupled with the variations due to distortion, led to the approximate method described above. To use it without the companion distortion model would give results that are not representative of the NAD27 system. This is because the distortions have regional trends that are seemingly random from one region to another, but are systematic within regions (Pinch, 1990; Boal and Henderson, 1988). Thus, significant advantage can be taken of the locally systematic nature of distortion.

Distortion Modelling

To model the distortion between the two systems, the original ESTPM (Estimation of Secondary Terrestrial Positions for Mapping) was selected as an appropriate tool. It had been developed specifically for this purpose (Blais, 1979), and was favoured for the continuous surface of its data model. Also, it had been in production use for more than 10 years for the integration into NAD27 of satellite survey networks. These networks covered wide areas, which precluded the use of constrained adjustment techniques into a set of values for the control survey network which contained significant local distortion.

Production use had been on an area-by-area basis, with each area being bounded by a major loop of the primary framework. No transformations were performed in the immediate neighbourhood of the high-density control, because satellite networks were generally established to densify large areas at about 80 km spacing.

• *Is the version of ESTPM used in the National Transformation the same as the one on the GHOST library that I have been using for years?*

When some detailed analyses were made of the behaviour of the ESTPM data model as applied to the national system of control networks, it was found that some fundamental assumptions of the original implementation did not apply. The two key items that indicated the need to modify ESTPM were:

1) the unusual distribution of residuals to the polynomial model when the residual interpolation feature was disabled, and

2) the unexpected localization of distortion in the intervals between control points when the residual interpolation feature was enabled.

The first problem was addressed by making changes to account for the extreme range of latitude - and thus the interval between meridians of longitude - required to cover all of Canadian territory. The units of displacement were converted from seconds to metres, and the computation plane was converted from a rectangular grid of latitude and longitude to a projection accounting for the convergence of meridians of longitude.

The second problem was a result of the large variation in the density of control survey stations throughout the country. The residual interpolation model used a weighting function (Blais, 1979) that assumed a constant value (**k**) against which the distances (**d**) to surrounding points were compared in the form

$$e^{-(\mathbf{d}/\mathbf{k})^2}.$$

To briefly summarize the characteristics of this function, a point very near to a control point (i.e. $\mathbf{d}\to 0$) would have a weight approaching one (the maximum possible value), while a point very far away (i.e. $\mathbf{d}\to\infty$) would have a weight approaching zero. A point at a distance **d=k** would receive a weight of ~0.4 .

It can clearly be seen that a fixed value for **k** would produce weights that are much too large in areas of high density, with the result that points that are many legs of surveying away - and thus with many opportunities to be under the influence of different distortion-producing constraints - would exert too great an influence on the residual interpolation process. Conversely, it can be shown that too small a value for **k** in areas of low density tends to localize the legitimate distortion that exists between adjacent control points to a small portion of the total interval between the points, thus producing a step-like function rather than a smooth transition.

To handle this much more complex second problem, a variable weighting approach was adopted. A value for **k** was determined for each individual control survey point, based on the typical distance to its nearest neighbour in the network. This was implemented separately in a pre-processing program named NEARPT.

Other features added to ESTPM2 include:

- more detailed reporting of data matching anomalies on input,

- sorting of data by y-coordinate to reduce the amount of computation required during residual interpolation (this change alone reduced the computing time of a single run by a factor of 25 !),

- a separate report of inconsistent residuals to aid the detection of improperly identified and/or integrated points, and

- handling of 9-character station identifiers as used in GHOST.

In developing the National Transformation, the decision was made to treat the datum transformation separately using program SCTRANS, and also to treat the plotting analysis separately, using program PLOTMB. These two aspects of the original ESTPM program were removed from ESTPM2, to alleviate the overhead of maintaining duplicate tasks in separate implementations.

Also developed as a separate application was the statistical analysis of the residuals, using program ESTAT. This utility routine uses the GHOST chi-square goodness-of-fit analysis and histogram plotting, and divides the data into a number of separate files for plotting.

• *So, now can I just get this new version of ESTPM and use it with the two sets of values I have for the handful of control stations in my area, and transform my data to NAD83?*

What must be realized is that the ESTPM software is only one of the components that determine the differences in coordinates at any given point, and does ***not*** produce unique results. The other main components are the common points selected from each system, the degree of the polynomial specified and the various residual interpolation options used, each of which is a very subjective process. To change any one would produce results that are noticeably different from the published National Transformation, thus destroying the need for users to have a consistent and reliable standard.

Data for Distortion Modelling

• *If Geodetic Survey has computed this transformation, how much good will it be to me in my area where there is no federal control nearby, and I rely on regional control networks?*

In addition to the more than 7,000 stations of the primary control network established by the Geodetic Survey of Canada, almost 100,000 secondary stations were included in the simultaneous integration adjustment to realize NAD83 in Canada. The survey observations for these stations were assembled in a cooperative effort involving both federal and provincial surveying agencies, through the Canadian Control Survey Committee (Pinch, 1990). Through similar cooperation of this same committee, as many of these stations as possible were used as common data points to define the distortion model between NAD27 and NAD83.

Provincial and federal survey agencies provided their currently published NAD27 values for stations within their jurisdiction to provide differences with the NAD83 values already on hand from the adjustment. At the primary control network stations, provincial values were compared to those published by Geodetic Survey to ensure that the NAD27 provided a basically consistent system amongst agencies. This exercise was a very positive one, confirming that the inter-agency communication (often assumed without question) was indeed working.

There were notable exceptions to the availability of NAD27 and NAD83 values for some provincial networks, however. The three Maritime provinces readjusted their networks on a geocentric system (ATS77) more than 10 years ago. Because of their continuing commitment to ATS77, they did not include the data for their 50,000 secondary stations in the NAD83 adjustment. Even though Quebec did include all of their secondary data in the NAD83 adjustment, they had recomputed their entire network on the NAD27 datum in the CGQ77 adjustment, which rendered it incompatible with the NAD27 system in use elsewhere in the country. Thus, in these four provinces, the distortion has been modelled based on the federal values for the primary control network only. These are the only major exceptions to the inclusion of secondary networks.

Apart from these exceptions, every effort was made to use all control survey points that were included in the NAD83 simultaneous secondary integration adjustment completed in June, 1990. Only stations considered to have NAD27 values that were grossly inconsistent with the surrounding network were removed, to prevent unwarranted bias in the distortion model. The general criteria followed was; if the coordinates were doubtful for use as reliable survey control, they would be removed and investigated by the responsible agency at a later date.

Some of the more typical situations that arose for questioning NAD27 data included:

- approximate coordinates that may have been scaled, or have preliminary or unintegrated values, which are generally indicated by the lack of significant digits after the decimal in the seconds field for latitude and longitude;

- stations for which reliable NAD27 values were not available from the controlling agency, because a current integrated adjustment had not been performed;

- inconsistent values for stations separated by only a few metres, often a result of networks overlaying each other (from different time periods), which were not integrated or maintained up-to-date.

• *If data for Quebec and the Maritimes were not included in the National Transformation, how will I transform my data in these regions?*

For the two cases of special provincial reference systems (ATS77 and CGQ77) as mentioned above, the provincial agencies will be developing separate transformations for use in these areas. Users whose data was compiled based on federal NAD27 control values, or on National Topographical System mapsheets, can use the National Transformation .

As with all other jurisdictions, users should contact the responsible agencies to obtain information about the version that is officially recognized and its relationship to the National Transformation.

• *How does this transformation work in the offshore areas where there are no control survey points established?*

To extend the definition of the transformation for users with interests in the offshore regions of Canadian territory, a few artificial control points have been added to the data set of actual control survey stations. Offshore control points were arbitrarily designated based on the nearest primary Doppler stations along the coastlines, and propagated as rays of 500 and 1000 km. The shifts at these points were assigned the same values as the shore points from which they were propagated. This simulates the relative positioning using satellite receivers that has been used extensively in offshore surveys.

• *Can I use this transformation with all of my NAD27 data?*

Although the National Transformation is universally applicable, we must remember that the NAD27 label has been generally applied to both the datum and to the coordinates of control survey points that are the realization of the datum. Because it is possible to have more than one set of coordinates referred to the same datum as a result of computations from different epochs (Junkins, 1988; Pinch 1990), the user must first determine how his NAD27 values relate to the current "official" values used in defining this transformation. Any significant discrepancy should be compensated for externally before using the National Transformation.

Accuracy of the Transformation

• *How accurately does this transformation produce coordinates in the new system?*

The purpose of this transformation is to predict what would happen if data which had been compiled in one system were to be recompiled into the other. The assumption is made that any such data would be directly connected to, or in some way derived from the primary and secondary control network stations in the immediate neighbourhood. It is also assumed that such a recompilation would uniformly distribute the distortion over the intervals between control stations.

Because knowledge of the differences between the two systems for these inter-station intervals is not generally available, a good estimate of the accuracy is not easily made. What are available are the residuals from ESTPM at the common points that were used to define the distortion model. These residuals exist since the model is not one that passes exactly through all the data points - a typical problem when working with an irregular distribution of points.

A summary of the residuals is given in Table ??? *in prep.* For 82% of the cases, the model predicts to within 10 cm of the actual difference, and in 96% of the cases it is within half a metre. The plot in Figure ??? *in prep.* shows the locations of those data points for which the residuals are greater than half a metre. This indicates to users the areas in which they might have slightly less confidence in the use of the transformation.

As some of the provincial agencies proceed to integrate their lower-order networks by adjustment of survey observations, more information will become available indicating how well their results compare to the predicted values. In making such comparisons, an important factor that must be kept in mind is the accuracy and reliability of these lower-order networks. Any discrepancy with predicted values is a function of inaccuracies in both the predicted and computed coordinates.

This transformation should satisfy the requirements of most users whose survey data is of lower accuracy than the control networks, and for digital mapping applications at most scales. Some exceptions are dealt with in the following discussion. It will also serve well those whose data is one or more steps removed from being directly tied to the control survey network, such as geographical information system data compiled by digitizing from a map base or by remote sensing, for example.

• *But I have a very dense network in just a small area with accuracy much better than 10 centimetres!*

For municipal control surveys and other dense, high-accuracy networks, some other factors need to be considered. First, was the basic municipal/local control network included in the readjustment project and the transformation data set? If so, then a reasonable model will be provided over the area of concern, but a denser grid than the nominal 5 minutes might be required. If not, then further modelling may take place after local control surveys have been integrated. In either case, consult the responsible provincial agency for official status and plans in the area of interest.

Secondly, is there significant distortion over the area, resulting in intolerable changes to dimensions (relative positions of points)? In this case, the next question that needs to be asked is - how was the local network connected to the control network? In many cases, there may be connections to only one or two stations, indicating that a local datum change should be considered as an alternative option. If the local network is more solidly connected, then perhaps its influence is required by simultaneous readjustment of the these survey observations together with the control network. If the distortion is valid, then the user should question the accuracy of his NAD27 dimensions and why he wishes to preserve them.

• *Why are there large residuals in some areas, and if confidence is reduced, what should I do about it?*

The mathematical models used in ESTPM assume that neighbouring points are directly connected by survey observations that are free of blunders, the typical status of integrated networks. Discontinuities in the control network pose a particular problem. The smooth surface of the model may not handle this situation adequately. Users should be alerted to these areas by the indications on the plots of large residuals distributed with the transformation. If the magnitude of these residuals is intolerable for an application, it is up to the user to determine to which of the neighbouring control values their data is related, and compute local shifts. This is virtually the same situation as data compiled on control values from earlier epochs.

In all cases, if retention of relative accuracy is the prime concern, then recompilation of the survey observations into the revised survey control network is the preferred solution. Transformation is an approximate method only.

The Grid Implementation

• *My business doesn't have any powerful computers like the VAX to run ESTPM2. How am I going to be able to do this with only a desktop or personal computer? Will Geodetic Survey Transform my data for me?*

To simplify the application of the National Transformation model to users' coordinate data, the commonly used approach of generalizing the modelled differences by a regular grid was adopted. This is similar to the implementation of the NADCON system developed by the United States National Geodetic Survey for the same purpose within U.S. jurisdiction (USNGS, 1989).

The objective of this approach is to make the model available in an automated form that will run on the smallest of common personal computers, without the requirement for large amounts of memory or high speed processing demanded by a routine such as ESTPM2. As stated in the SMRSS policy document on NAD83 (Canada Centre for Surveying, 1990), Geodetic Survey will not operate as a service bureau to transform users' data. Instead, this simplified implementation is designed to make users self-sufficient.

• *The transformation will be based on the Grid - this is great! I'll be able to get the shifts to my UTM coordinates and go directly to NAD83.*

It must be emphasized that all references to the term "grid" in the context of the National Transformation are meant to imply points at regular intervals (of arc) of latitude and longitude. There has not been a corresponding set of tables made up for plane coordinates (often referred to as the reference "grid") for a few reasons:

- there are several projections in common use in Canada (eg. Transverse Mercator, Stereographic, Lambert, Polyconic, etc.), and variations within each of these, making it difficult to choose any one to be definitive, and prohibitive to produce versions for all;

- if the most common plane projection (UTM) were chosen, should the grid points be selected at regular whole intervals of plane coordinates, or should they correspond to the projected values of the ellipsoidal grid? ;

- if the ellipsoidal grid were projected into corresponding plane values, the table look-up algorithm would fail since the intervals would no longer be regular. Also, the bilinear interpolation would not provide identical results on the plane as on the ellipsoid;

- if a regular grid were used in the projection plane, inconsistencies in resulting values would occur in the neighbourhood of zone boundaries, since interpolation at the same point using tables for adjacent zones would produce slightly different results.

Keeping in mind that the main objective of the grid implementation is to simplify the process and to provide a unique result for all users, the choice to define the grid in terms of ellipsoidal coordinates seems the most straightforward.

• *Then how will I handle my data, which is all in UTM values?*

To accommodate most users of plane coordinates, the Transverse Mercator projection has been built into the grid interpolation software. Values may be optionally supplied in the form of plane coordinates, which are internally converted to corresponding ellipsoidal coordinates, and the shift computed in the default ellipsoidal system. On output, the transformed values are converted back to plane coordinates - either in their default zone (which may have changed), or in their original zone, at the option of the user. Variations such as zone width, central meridian, and false eastings and northings are user selectable options.

• *Will I be able to get the transformation in both ESTPM2 and the Grid formats?*

Again for the sake of uniqueness, the grid implementation is the only form in which the National Transformation will be published. The ESTPM2 solution for a point would be slightly different than the bilinear interpolation result. Since these differences are well within the accuracy of the distortion model in most areas, no hardship will be imposed on users. Some provincial agencies have indicated their desire to densify the grid using intervals smaller than the nominal 5 minutes of arc, to better handle areas of very dense control with significant local distortion. This will be done as a subsequent exercise, once the areas requiring such treatment have been identified.

Grid Software and Data Files

The grid interpolation software for the National Transformation is actually a suite of programs, focused around the files of grid shift data. It is independent of the software and modelling techniques used to transform between two systems, and can be used with any pair of systems. All that is required are one file of coordinates in a regular grid, and its counterpart that has undergone some transformation process. It works in both directions between the two systems.

The following are brief descriptions of the programs. More detail can be found in the accompanying Software Documentation and User's Guide (Farley & Junkins, 1990).

Program **INTGRID** accepts coordinates for a point supplied by the user, performs the lookup of grid points for the appropriate quad, and interpolates within the quad to produce the shift at the point. This shift is applied to the original coordinates to produce transformed values.

Program **INTTAB** produces a tabulated printout of a selected area of the grid file. This produces a two-dimensional representation of the selected area, enabling the user to more easily visualize the differences between the two reference systems. The printout is also useful for manual interpolation if only a few points require transformation.

At the heart of these two processes is the **Grid Shift File**. It is a system-specific, unformatted direct-access file with one grid point per record. As such, it is virtually unreadable by the user, and thus not easily altered by mistake. The header records included at the beginning of the file provide such information as the limits of the grid, the sizes of the grid intervals, the units of the shifts, and the names and ellipsoid parameters of the "to" and "from" reference systems. The data records each contain a pair of shifts - one for latitude and one for longitude. The coordinates of the grid point are not included - the appropriate record number in the file can be calculated from the header data.

The Grid Shift File is created by program **DIRFIL**, which reads two separate files of GHOST format coordinate records and takes the difference between the values to produce the shifts. After obtaining the necessary information through an interactive dialogue with the user, the program forms the header records, and follows them with the grid shift records. The files of grid coordinates may be windowed by the limits set by the user. Data is checked to ensure the integrity of the grid files being processed. This exercise needs to be performed only once to establish the Grid Shift File for an area, unless a user wishes to migrate the file to a different computer platform.

The utility program **READDA** allows the user to obtain a formatted printout of the Grid Shift File, with the option of listing either the complete file or only the header information. This can be useful for verifying the creation of a new file, or checking the contents of an existing file.

Program **GRIDPT** generates a regular grid of ellipsoidal coordinates to initiate the implementation of the grid shift approach. While it is included in the suite of programs, it is of little use to most users, since they will not have ready access to the ESTPM2 distortion model to generate the corresponding file of transformed grid values. Note also that there is no point in densifying the grid using the bilinear interpolation, since the results would be identical.

Program **GSRUG** converts between ellipsoidal and Transverse Mercator forms of the same coordinate. It is taken from the GHOST library, and is included for converting externally rather than within program INTGRID. Users who wish to convert from one standard of plane projection to another (eg. from 3°MTM to 6°UTM) while making the move to NAD83 may find this useful.

• *What computer will this software require? Will I have to buy a PC, or can I run it on my SUN Workstation?*

All of this software has been written in FORTRAN 77 code, keeping as close to the ANSI standard as possible. It has been implemented on three platforms - IBM/PC compatibles, Apple Macintosh, and Digital VAX/VMS. The same source code is used on all three with minor exceptions. Where these exceptions do occur, statements for all three systems are embedded in the source code with identifying comments. The inappropriate lines are commented out before compilation. No significant amounts of memory are required to load or execute any of the programs. The result is a package that is easily migrated to any platform with a FORTRAN compiler.

• *I don't have a large hard disk for my PC. How am I going to handle the data files for all those grid points?*

At a grid interval of 5 minutes, there are 144 points per 1°x1° area. With the vast area of Canadian territory, plus the offshore regions for which this transformation is required, a single grid file is not practical for many applications. It could take as much as 10 megabytes of disk space. To reduce the storage required on-line for users of small systems, the country will be partitioned into smaller areas. For distribution in PC format, Grid Shift Files will be kept to a size that fits on standard floppy diskettes.

Users wishing to create their own Grid Shift files from the two files of GHOST format coordinate records will temporarily need significant hard disk space to hold these two files, since each is about five times the size of the resulting direct access file. The windowing is easily accomplished with program DIRFIL, and only needs to be done once for each windowed area, as mentioned above.

• *If the grid files are partitioned into areas, are they discrete or will they overlap? Will I get the same results from different partitions in the overlap area, or if I use a "windowed" subset?*

All grid files can be considered a subset of a single, large master file. Since only the four points at the corners of a quad are used to determine the shift at any point within the quad, any subset containing these four points will produce identical results.

• *The possibility of "densifying" the grid was mentioned earlier. How will that be compatible with the standard grid?*

A denser grid can be produced for any regular quadrilateral area designated by a responsible agency as having significant local distortions that are not adequately handled by the standard 5 minute grid spacing. The shifts at the additional grid points that are interior to the selected quad would be computed using the same datum and distortion models and parameters. At grid points falling along the lines bounding the area, however, the linear interpolation values would be retained to ensure that all points have unique results (see Diagram ??? *in prep.*). Notification to alert users of such specialized areas would be handled by the agency producing them.

• *This brings up the possibility of different versions. What will happen when you resolve problems with some of the control points that had to be left out, or integrate new surveys? We can't afford to update our data base annually!*

The possibility of new versions of the transformation certainly does exist, but no more so than for the control network itself. As investigations of existing NAD27 anomalies and further integration of other existing networks not yet included in NAD83 progress, the model will continue to be improved. The addition of newly performed surveys will have negligible effect on the transformation, since they will cause little change in existing NAD83 values, and there are no corresponding NAD27 values to add to the transformation model.

Every effort will be made to retain the existing values published for the shifts, unless there are overwhelming differences that the responsible agency deems significant in terms of the accuracy of the estimates. Probably most such cases could be handled locally in a similar fashion to the grid densification described above. As such changes accumulate, eventually a new version will likely be published. Again, consult the appropriate agency to obtain the official status.

This does underscore the requirement to tag all coordinate data with both the reference datum and the source of the computation on that datum, such as the date of adjustment or the version of the transformation. Such information allows the user to readily identify and resolve discrepancies among coordinates from various sources, since the tags give enough information to trace the exact relationships.

Summary

• *Why should I use this rather than just work out something simple for my own small area?*

There really aren't any methods simpler than interpolating within a grid that can handle variable differences, as required just by the change in reference ellipsoid without even considering distortion. This technique was commonly used with tables for functions of more than one variable in the days of log tables and sharp pencils.

Most federal and provincial jurisdictions, represented by their survey and mapping agencies on the Canadian Control Survey Committee of the Canadian Council for Geomatics, will officially adopt this transformation. Local variations will be smoothly integrated and become part of the overall unique specification.

Use of this standard will ensure results that are identical to those obtained by other users, thus optimizing the usefulness of the new standard reference system NAD83.

This transformation has already been prepared and is supported by the same agencies that produce and distribute NAD83 control survey coordinates. It only has to be used without any investment in development on the part of the user.

• *When shouldn't I use this transformation?*

As mentioned previously, this transformation is based on NAD27 values for control survey points as currently published by federal and provincial agencies. If data that the user wishes to transform to NAD83 is based on these values from another epoch, or are referred to a local datum or some other variation, then these differences need to be accounted for. Such inconsistencies will only be preserved in the transformed coordinates.

Quebec and the Maritime Provinces have special local systems for which a different transformation will be required. These and other federal and provincial agencies can provide assistance to determine what the differences are, and whether they might be significant for a specific application.

Transformations in general should not be used with the intent of improving the accuracy of coordinate data. Existing systematic errors and blunders will be preserved, and have the local error (inaccuracy) of the transformation added to them.

Neither this transformation nor any other should be used to migrate reliable control surveys to NAD83. The survey observations should be readjusted to properly integrate them, and to produce accuracy estimates for the resulting coordinates.

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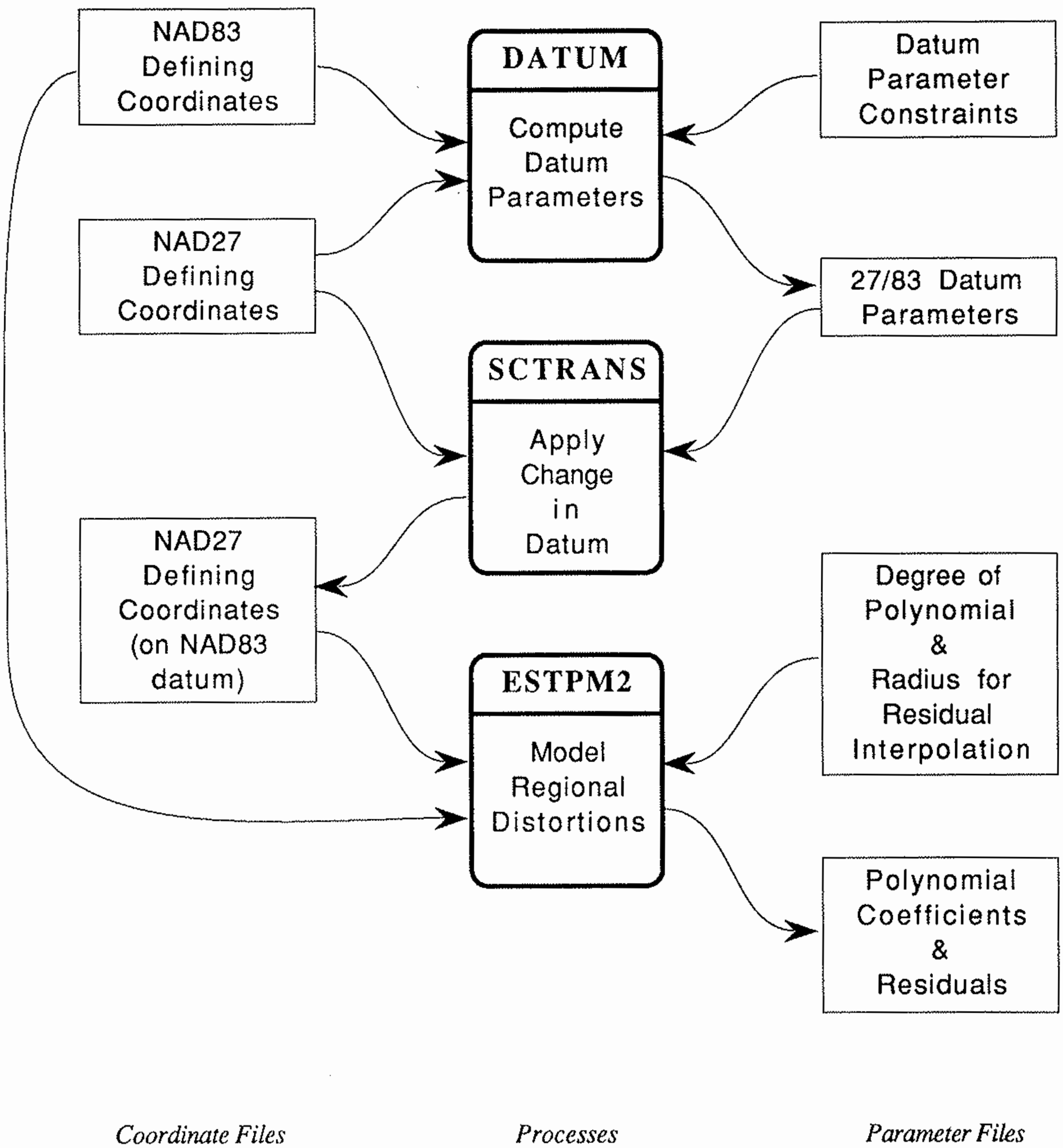
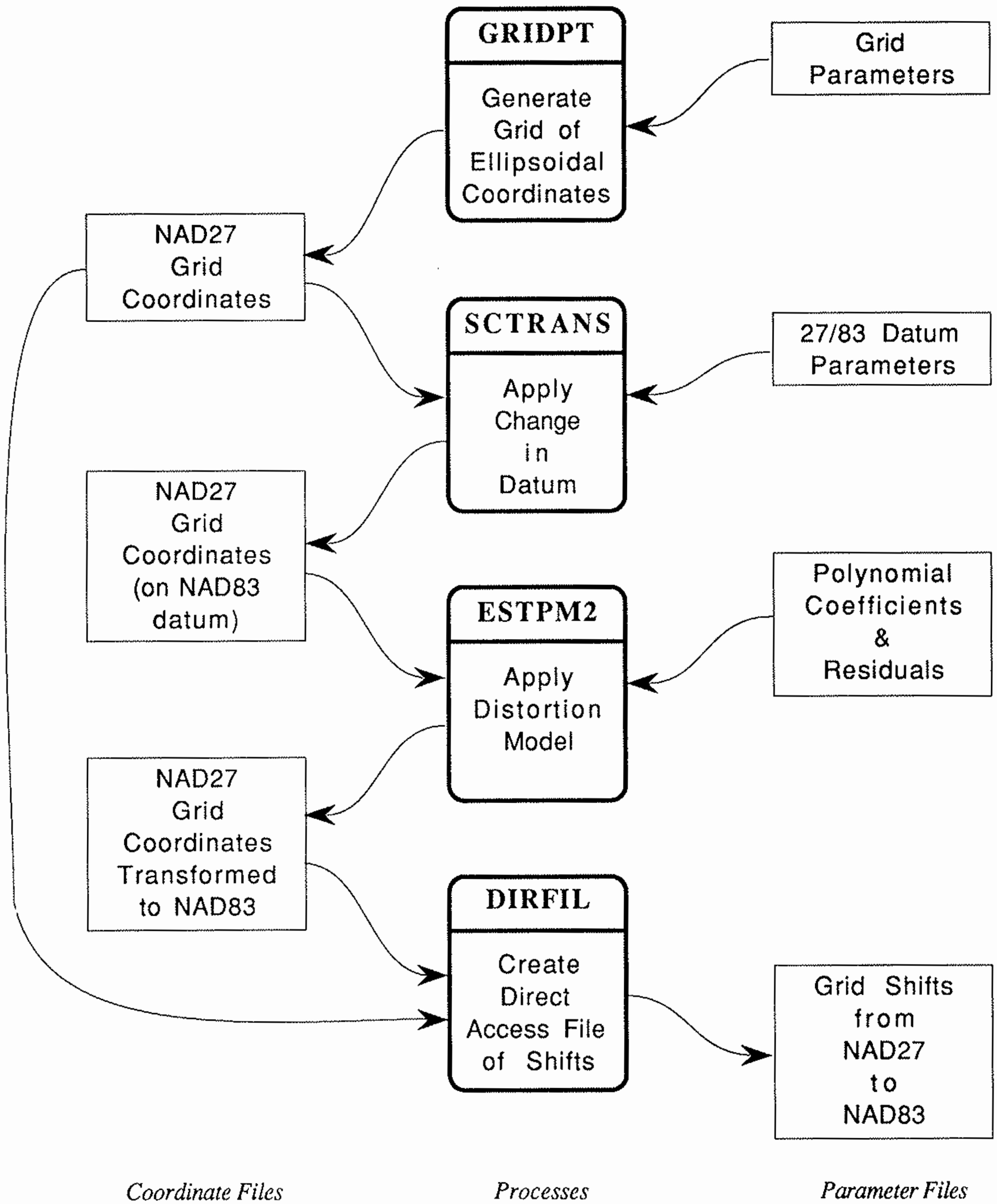
NATIONAL TRANSFORMATION
Define Parameters



NATIONAL TRANSFORMATION
Create Grid Shifts



NATIONAL TRANSFORMATION
Transform Coordinates
Using Grid Shifts