Tutorial

Coordinate Reference Systems

with
TNTmips®
TNTedit™
TNTview®

Before Getting Started

A coordinate reference system defines how your georeferenced spatial object relates to real locations on the Earth's surface. A common interface is used throughout the TNT products for selecting or defining a coordinate reference system for geospatial data or geospatial operations. This booklet introduces you to the Coordinate Reference System window and its operation.

Prerequisite Skills This booklet assumes that you have completed the exercises in the tutorial booklets *Displaying Geospatial Data* and *TNT Product Concepts*. Those exercises introduce essential skills and basic techniques that are not covered again here. Please consult those booklets and other TNT reference materials (installed or on MicroImages' web site) for any review you need.

Sample Data Some of the exercises presented in this booklet use sample data that is distributed with the TNT products. If you do not have access to a TNT products DVD, you can download the data from MicroImages' web site. In particular, this booklet uses in the CB_TM Project File in the CB_DATA data collection.

More Documentation This booklet is intended only as an introduction to coordinate reference systems. Details of using coordinate reference systems can be found in a variety of tutorial booklets, Technical Guides, and Quick Guides, which are all available from MicroImages' web site (go to http://www.microimages.com/search to quickly search all available materials, or you can narrow your search to include only tutorials or TechGuides).

TNTmips® Pro and TNTmips Free TNTmips (the Map and Image Processing System) comes in three versions: the professional version of TNTmips (TNTmips Pro), the low-cost TNTmips Basic version, and the TNTmips Free version. All versions run exactly the same code from the TNT products DVD and have nearly the same features. If you did not purchase the professional version (which requires a software license key) or TNTmips Basic, then TNTmips operates in TNTmips Free mode.

All the exercises can be completed in TNTmips Free using the sample geodata provided.

You can print or read this booklet in color from MicroImages' Web site. The Web site is also your source for the newest tutorial booklets on other topics. You can download an installation guide, sample data, and the latest version of TNTmips Free.

***http://www.microimages.com***

Welcome

TNTmips provides the most advanced software for creating, displaying, processing, and analyzing all types of geospatial data. The "*geo*" in *geospatial* means that the data objects in your TNT Project Files include spatial reference information that relates the features portrayed in these objects to positions in the real world. Geospatial referencing enables TNT processes to accurately overlay different geodata layers for display and processing, to report real-world positions of features in View windows, and to reproject (warp) geodata objects when necessary (among other procedures).

Spatial referencing for image or map data can be set up manually using the Georeference process or assigned when you import geospatially-referenced data from an external file format, such as a GeoTIFF file. Geographic locations in a geospatial object are specified in terms of the object's **coordinate reference system**. A coordinate reference system combines a **coordinate system** with a **datum**, which gives the relationship of the coordinate system to the surface and shape of the Earth. A coordinate system may also include a **coordinate transformation** (traditionally called a **map projection**) that relates positions in geodetic coordinates to positions in the coordinate system. Definitions for terms in bold type above and on subsequent pages can be found on the inside back cover of this booklet. Additional conceptual background information can be found in the tutorial booklet entitled *Introduction to Map Projections*.

The Coordinate Reference System window is used throughout the TNT products to set the coordinate reference system for a geospatial object or for a geospatial operation. You can choose from hundreds of predefined coordinate reference systems, thousands of combinations of coordinate systems and datums, or create and save specialized private coordinate reference systems.
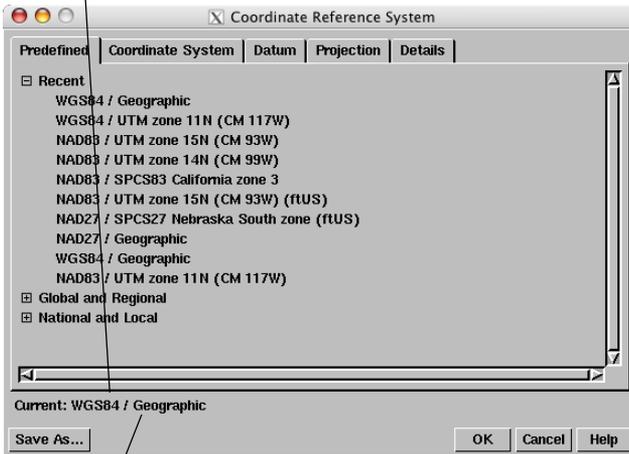
STEPS
- ☑ choose Tools / Map Calculator from the TNTmips menu
- ☑ in the Coordinate Reference System 1 groupbox, press the Specify button to open the Coordinate Reference System window
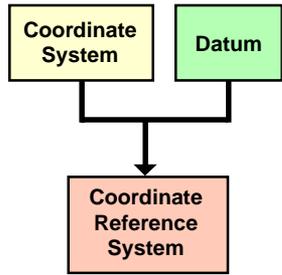
The Coordinate Reference System window and the spatial referencing standards it implements are introduced on pages 4-5. Pages 6-13 show you how to select or set up a coordinate reference system using predefined components. Backward compatibility warnings are discussed on page 14. Pages 15-18 cover setting up and saving private coordinate reference systems and a utility for changing settings for incorrectly-referenced data. A short glossary of spatial referencing terms can be found on page 19.

Coordinate Reference System Window

The controls on the Coordinate Reference System window are organized on tabbed panels. The Predefined panel is shown by default when the window opens. This panel presents a scrolled hierarchical listing of hundreds of predefined coordinate reference systems that can be selected in a single step, including many that are tailored to particular nations or states/provinces. On this panel you can also select from several globally-applicable coordinate systems such as Universal Transverse Mercator that can be paired with any available datum to form a coordinate reference system appropriate for any specific area.

The coordinate reference system that is currently in use or selected is shown at the bottom of the Coordinate Reference System window. This field is automatically updated as you make or change selections.

The Datum tabbed panel allows selection of a datum and accompanying **datum transformations**. In the majority of cases you can complete the selection of your desired coordinate reference system using only the Predefined and Datum panels.

In the event that the required coordinate reference system is not provided on the Predefined panel, you can use controls on the Coordinate System, Datum, and Projection panels to specify all of the elements of your private, custom coordinate reference system, and save it for later use. Once you have selected or set up a coordinate reference system, all of its particulars are listed on the Details tabbed panel.

If you open the Coordinate Reference System window from a process that is using georeferenced data, the "Current" coordinate reference system is set from that data. If you open the window with no geodata in use or selected, as in this example, this field defaults to WGS84 / Geographic (longitude / latitude coordinates using the World Geodetic System 1984 datum).

☑ keep the Coordinate Reference System window open and proceed to the next exercise

Spatial Referencing Standards

In order to facilitate the exchange and use of geospatial data by different individuals and organizations, it is important to have a common framework and structure for expressing spatial referencing information. To further this goal, the specification of coordinate reference systems and their components in the TNT products conforms to the International Organization for Standardization (ISO) standard 19111:2003 entitled *Spatial Referencing by Coordinates*, which in turn encompasses the Open Geospatial Consortium's (OGC) Abstract Specification of the same name. These standards define the elements necessary to fully specify a coordinate reference system and also provide a uniform framework for **coordinate conversions** and for **coordinate transformations** between different coordinate reference systems.

Although these ISO and OGC documents specify how a coordinate reference system should be defined, it is up to each geospatial analysis system to provide all of the actual geodetic parameter values needed to define the hundreds of coordinate systems and datums that are in common use throughout the world. The European Petroleum Survey Group (EPSG) Geodesy Parameters database is used by the TNT products as the source for most predefined coordinate reference systems, coordinate systems, and datums provided through the Coordinate Reference System window. This widely-used data source has been incorporated in the GeoTIFF data exchange specification as well as in other data models. The EPSG database is updated regularly with parameters for newly-added datums and coordinate systems. As they become available, these updates are also incorporated in the TNT products and are distributed with the weekly software updates for the latest version of the TNT products. In addition, the TNT products also provide certain coordinate reference systems or their elements that are not found in the EPSG database.

European Petroleum Survey Group

By conforming to international standards for spatial referencing and incorporating the EPSG database, the TNT products provide you with a robust yet flexible foundation for all spatial operations with your data.
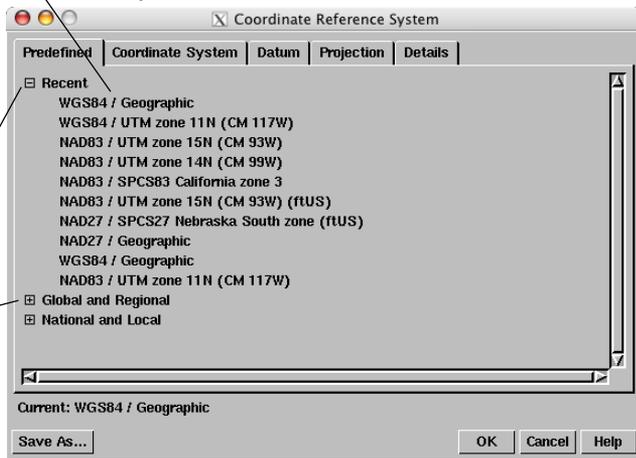

Request Additional Coordinate Reference Systems

If coordinate reference system components you routinely use are not available in the Coordinate Reference System window, you can ask MicroImages to add them at no cost to you. Your request must provide all the required parameters for the new datum, datum transformation, coordinate system, or map projection. Updates to coordinate reference systems are implemented as part of the regular patches to your current version of the TNT products.

Predefined Panel

The Predefined panel uses an interactive tree control to organize its selections into hierarchical groups that you can expand or contract as needed to show or hide their contents. The highest-level groups on the Predefined Panel are Recent, Global and Regional, and National and Local. The Recent group lists the last ten coordinate reference systems you have selected in any TNT process. For your convenience, the Recent group is automatically expanded when you first open the Coordinate Reference System window, allowing you to select any of these recently-used entries in one step. The coordinate reference system set as "Current" when the window opens is always listed at the top of the Recent group.

Your Recent group undoubtedly lists a different set of coordinate reference systems than those shown here, and it may have fewer than 10 if you have just begun using TNTmips or you routinely work with a small number of coordinate reference systems.

Click on the box control to collapse an expanded group ("-" sign inside the box symbol) or expand a collapsed group ("+" sign inside the box symbol).

☑ keep the Coordinate Reference System window open and proceed to the next exercise

Group headings at any level in the Predefined list have a box-shaped symbol to the left of their entry. This symbol is a control button that you left-click to expand the group to show its contents or collapse to hide its contents. The symbol inside the box control changes from "+" when the group is collapsed to "-" when the group is expanded. You will use these controls as we explore the other main groups in the Predefined list in the next exercise.

National and Local Group

As their names suggest, the Global and Regional group and National and Local group subdivide coordinate reference systems by their geographic extent. The National and Local group includes subgroups for many individual nations. Each of these subgroups can be expanded to find coordinate reference systems specific to that nation, such as the ones shown here for Antarctica. (Although not a nation, Antarctica has special status under international treaty and so is listed as a national group.)

All of the entries in the National and Local groups are complete coordinate reference systems that can be selected in a single step. (After selecting a coordinate reference system, you should also select appropriate datum transformations on the Datum panel, as discussed on a later page.) You can easily identify entries that represent a coordinate reference system: they be-

STEPS
- ☑ left-click in the box control to the left of the Recent group's heading to collapse it
- ☑ left-click in the box control to the left of the National and Local heading to expand it
- ☑ under the National and Local group heading, expand the Antarctica group
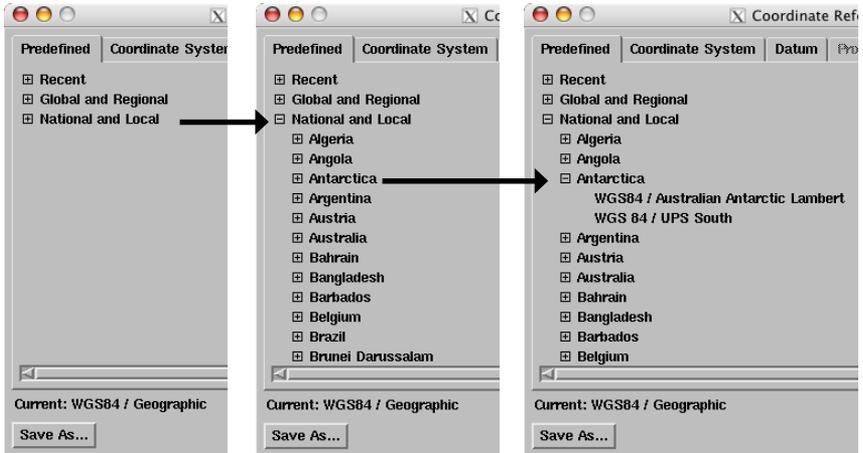
gin with the datum name followed by the "/" character, then the coordinate system name. In the Antarctica group there are entries for two coordinate reference systems that combine the same datum (WGS84) with different coordinate systems.

- ☑ leave the Predefined panel's tree list as shown in the right-hand illustration and proceed to the next page

US State Plane Coordinate System

STEPS
- ☑ collapse the Antarctica group
- ☑ using the vertical scroll bar on the right side of the Predefined panel, scroll down through the National and Local group and expand the United States group
- ☑ expand the group for the state of Alabama
- ☑ click on the first entry in the Alabama group to select it
- ☑ press [OK] on the Coordinate Reference System window to accept the current selection and return to the Map Calculator window

Some national groups in the Predefined panel are subdivided in various ways. China has a subgroup for each of two datums in common use there, with each subgroup including a set of geographic zones that collectively span the entire country. The Canada and United States groups have a subgroup for each province or state. Each group for a U.S. state includes entries for the United States State Plane Coordinate System (SPCS) zones for that state. These entries combine the SPCS zones with different datums to form complete coordinate reference systems.
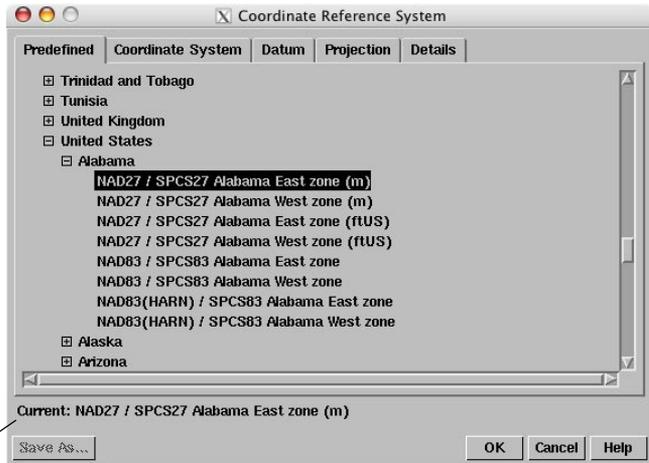
When you select a coordinate reference system, the Current field is automatically updated to show the selection.

The datums available for use with State Plane Coordinate zones are the North American Datum 1927 (NAD27), North American Datum 1983 (NAD83), and a version of NAD83 adjusted using the state's High Accuracy Reference Network (HARN). The HARN network for each state is a set of high-quality geodetic control stations that have been located using very accurate Global Positioning System (GPS) readings.

Units for US State Plane Coordinates

Zones within the US State Plane Coordinate System originally referenced the NAD27 datum and were defined using US feet as the measurement unit for the coordinate system. However, it is common to find geospatial data referenced to a NAD27 SPCS zone but using meters as the unit of measure.
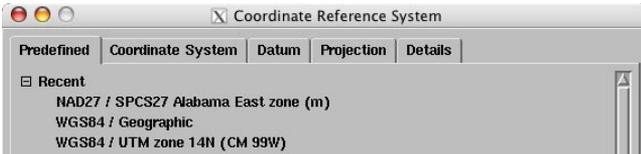
The definition of a coordinate system in the ISO19111 standard and in the EPSG database includes the measurement unit used to express coordinate locations. Therefore a coordinate system and measurement unit cannot be selected independently. Where a group in the Predefined list contains similar coordinate reference systems using different units, the measurement
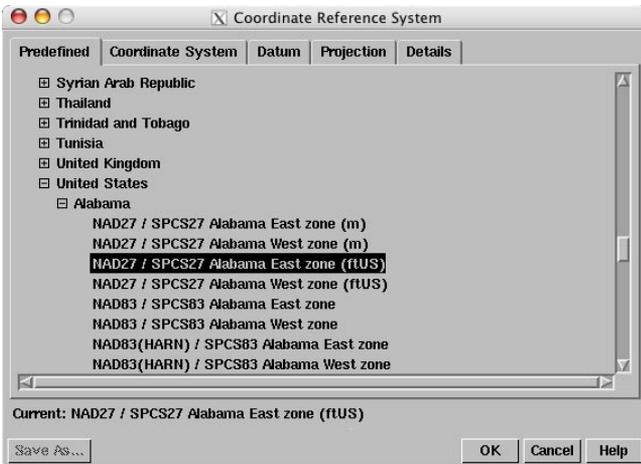
unit is identified in parentheses at the end of the coordinate system part of the list entry. To choose between feet or meters for a SPCS zone, select the appropriately labeled entry in the Predefined list of coordinate reference systems.

Global and Regional Group

STEPS
- ☑ collapse the National and Local group and expand the Global and Regional group
- ☑ expand the Asia subgroup in the Global and Regional group
- ☑ examine the Asia group entries, then collapse the group again
- ☑ expand the Europe subgroup in the Global and Regional group
- ☑ select the first entry in the Europe subgroup

The Global and Regional group includes entries for coordinate reference systems and coordinate systems that are not targeted toward use within a particular nation. This group includes a number of subgroups as well as several additional list entries.

The Asia and Europe geographic subgroups include entries for many complete coordinate reference systems appropriate for use within these continents. Most of the coordinate reference systems in the Asia subgroup combine the Pulkovo 1942 datum with various coordinate systems using the Gauss-Kruger zonation system (with a choice of 6-degree or 3-degree Gauss-Kruger zones).
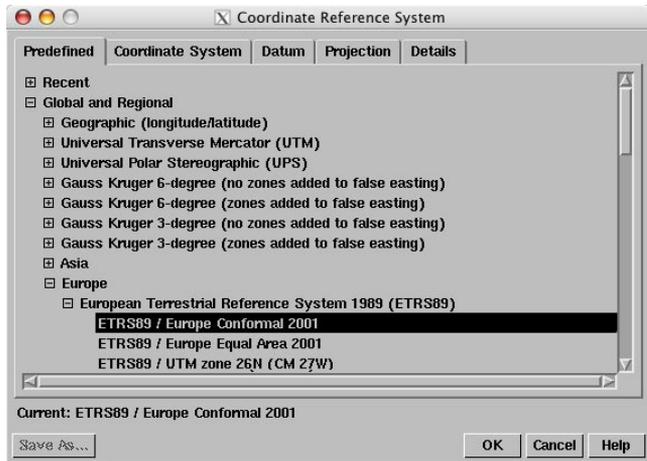
- ☑ keep the Coordinate Reference System window open with the current settings and proceed to the next exercise

The Europe subgroup includes coordinate reference systems that provide a choice of several datums in combination with either Universal Transverse Mercator (UTM) or Gauss-Kruger zonal coordinate systems. This subgroup also includes several Europe-wide entries (including the entry selected in this exercise).

Coordinate Reference System using UTM

The Universal Transverse Mercator (UTM) coordinate system divides the globe into a series of numbered zones that are 6 degrees of longitude in width and divided by the equator into north and south portions. Each UTM zone has its own planar coordinate system, and each zone has an entry in the Universal Transverse Mercator subgroup within the Predefined list's Global and Regional group.

When you select a UTM zone in the Predefined list, you are not selecting a complete coordinate reference system, but only specifying the *coordinate system* to be used. The datum already specified in the Current field (in this example ETRS89 from the previous exercise) is retained when you select a UTM coordinate system (zone). In most cases you will need to select a different datum on the Datum panel in order to create the desired coordinate reference system. We will show that procedure next.

STEPS
- ☑ collapse the Europe subgroup of the Global and Regional group in the Predefined list
- ☑ expand the Universal Transverse Mercator (UTM) subgroup of the Global and Regional group
- ☑ scroll downward through the list of UTM zones and select UTM zone 12N (CM 111W)

A subgroup is also provided in the Global and Regional group for each variety of the Gauss-Kruger zonation system. A Gauss-Kruger zone, like a UTM zone, specifies a coordinate system, but not a datum, and it is selected in the same way as a UTM zone.


scroll down through the UTM zones...
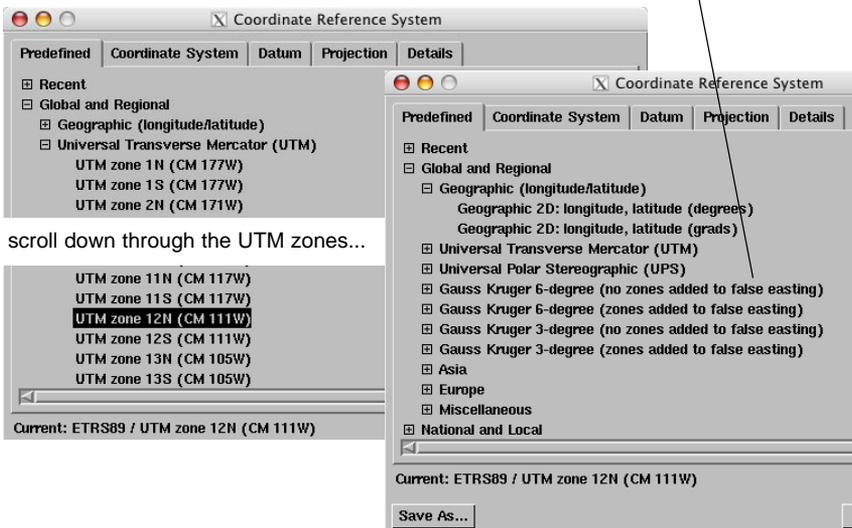
Select Datum

STEPS
- ☑ left-click on the Datum tab to expose its panel
- ☑ click on Datum combobox's icon button to show the scrolling list of datums
- ☑ scroll down and select North American 1983 (NAD83) from the datum list

Let's assume that the UTM zone you selected on the previous page, UTM zone 12N, is intended for use with geospatial data from Arizona, USA, and that the datum to be used is North American 1983 (NAD83). The Datum menu on the Datum tabbed panel provides an extensive list of datums from which you can choose. Some of these datums, such as World Geodetic System 1984 (WGS84), are designed for global use, but most were created for use in a particular country or region.
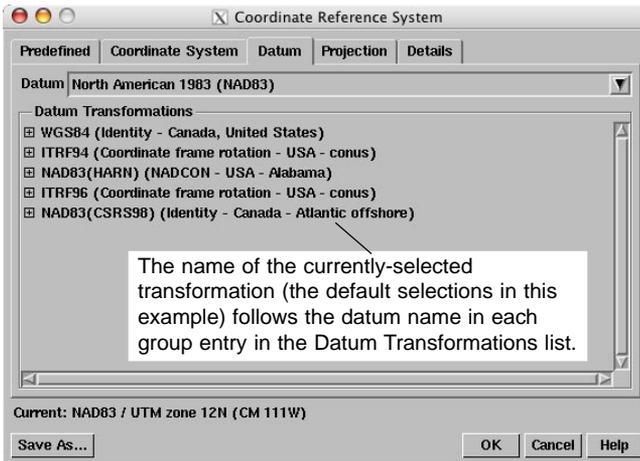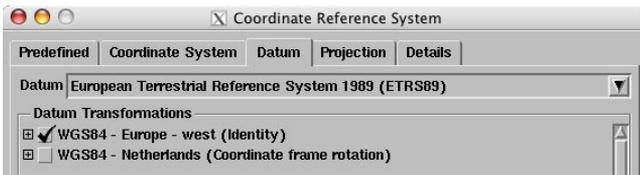
Once you have selected a datum (either directly on the Datum panel or indirectly by selecting a predefined coordinate reference system), you can select direct transformations to other datums (one per datum) using the Datum Transformations list on the Datum panel. This list uses the same type of controls as the Predefined list. Each available datum is

shown as a group entry in which you can find a list of transformations. We will select datum transformations for our current example next.

- ☑ keep the Coordinate Reference System window open with the current settings and proceed to the next exercise

Note: Direct datum transformations may not be available for the particular datum you selected because they are not mathematically defined or are not provided in the EPSG geodetic parameter database.

Datum Transformations

A datum transformation is used whenever a geospatial object (such as a raster or vector object) must be reprojected to register with another object georeferenced to a different datum. This situation can occur when objects are overlaid in a View window or used in other spatial processing.

A direct datum transformation provides the fastest and most accurate transformation result. If a direct transformation is not selected or is not available, positions are first translated to the WGS84 datum, then to the target datum. The two-step transformation may introduce slight positional inaccuracies compared to a direct transformation.

In some instances you can tailor your selection of datum transformations to the geographic location and scope of your data. Here we are setting up a coordinate reference system for data from the state of Arizona. When you are using the NAD83 datum, individual versions of the transformations to WGS84 and NAD83(HARN) are available for most states, including Arizona. Note that when you select a different transformation for a datum, the transformation name is updated in the group name for the datum. The global ITFR94 and ITFR96 (Internal Terrestrial Reference Frame) datums each offer a single transformation that is applicable throughout the continental United States (you may want to open these datum groups to confirm this), so there is no need to change these selections in this case. The NAD83(CSRS98) datum applies to offshore eastern Canada, so its transformation can be deselected.

STEPS
- ☑ expand the WGS84 group in the Datum Transformations list
- ☑ select the USA - Arizona (NADCON) transformation, then collapse the WGS84 group
- ☑ repeat the above steps for the NAD83(HARN) group
- ☑ collapse the NAD83(HARN) group
- ☑ expand the NAD83(CSRS98) group and deselect the Canada - Atlantic offshore entry
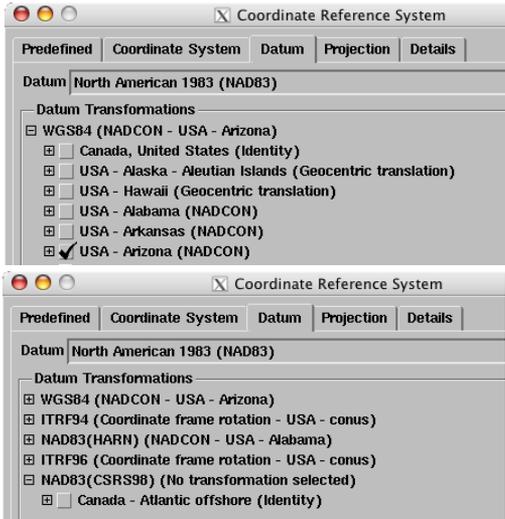
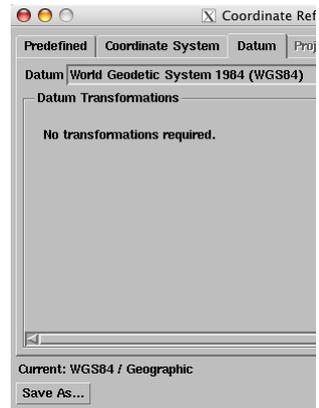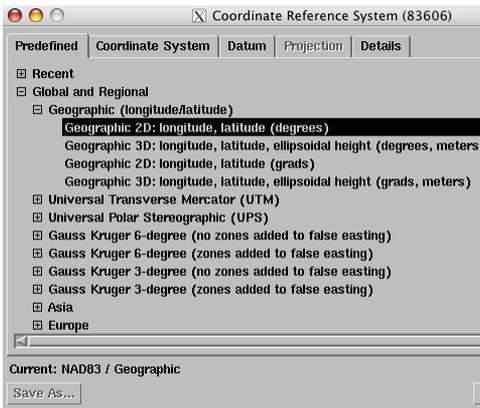- ☑ click [OK] on the Coordinate Reference System window to complete setup

Geographic Coordinate Reference System

STEPS
- ☑ press [Specify...] on the Map Calculator window to reopen the Coordinate Reference System window
- ☑ expand the Global and Regional group on the Predefined panel
- ☑ expand the Geographic (longitude/latitude) group
- ☑ choose *Geographic 2D: longitude, latitude (degrees)*
- ☑ on the Datum tabbed panel, select the *World Geodetic System 1984 (WGS84)* datum
- ☑ press [OK]

Global coordinate systems using latitude/longitude can be selected from the Global and Regional Group on the Predefined tabbed panel. They are found in the Geographic (latitude/longitude) subgroup. You can choose from 2D and 3D versions using either degrees or grads as the map unit. To complete specification of the coordinate reference system, choose the desired datum from the Datum tabbed panel.

Latitude/longitude coordinate systems reference locations directly to the surface of an ellipsoid using angles as coordinate units. Thus there is no map projection associated with such systems. Because of their simplicity and global applicability, latitude/longitude coordinates are widely used for publicly-available geodata. However, use of latitude/longitude coordinate can complicate display and spatial analysis. Because lines of longitude converge toward the poles, the horizontal distance equivalent to one degree of longitude varies with latitude. This characteristic complicates computations of distances and areas. For geodata of local or regional extent, use of a projected coordinate system using planar coordinates provides more accurate measurements and spatial computations.


Geodata using geographic (latitude/longitude) coordinates can be reprojected to a planar coordinate reference system. Use the Automatic Resample process (Image / Resample and Reproject / Automatic) or Geometric Warping process (Geometric / Reproject).

Saved Coordinate Reference Systems

You can name and save custom coordinate reference systems using the Save As... button on the Coordinate Reference System window. This button is active whenever the coordinate reference system you have assembled does not duplicate an existing predefined or previously-saved coordinate reference system. After you have saved one coordinate reference system, a Saved group is included in the Predefined selection list below the Recent group. You can then quickly select any of your saved coordinate reference systems from this group.

This exercise shows a simple yet very useful example. You might frequently use a particular UTM (or Gauss-Kruger) zone and datum. If so, you can save this combination as a coordinate reference system in your Saved group, where you will always be able to find it
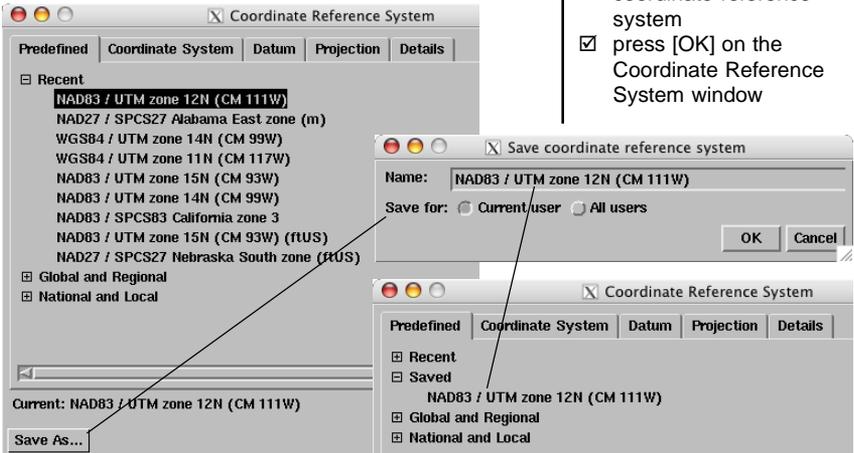
STEPS
☑ in the Recent group on the Predefined panel, select NAD83 / UTM zone 12N (CM 111W)
☑ press the Save As... button at the bottom of the Coordinate Reference System window
☑ accept the default settings provided in the *Save coordinate reference system* window and press its OK button
☑ note that a Saved group appears in the Predefined list and opens automatically to show your saved coordinate reference system
☑ press [OK] on the Coordinate Reference System window

and select it in a single step, rather than having to reselect its components or rely on it remaining in the Recent group since its last use.

☑ press [Close] on the Map Calculator window

Your saved coordinate reference systems are maintained separately from the predefined geodetic parameters provided with the TNT products. Your Saved group therefore is preserved when you patch or update to a more recent version of the TNT products.

Private Coordinate Reference Systems

STEPS
- ☑ choose Tools / Map Calculator from the TNTmips menu
- ☑ press [Specify...] on the Map Calculator window to reopen the Coordinate Reference System window
- ☑ on the Coordinate System tabbed panel, use the Coordinate System menu to select Projected: Easting(E), Northing(N) [meters]
- ☑ on the Datum tabbed panel, select North American 1983 (NAD83) from the Datum menu
- ☑ set the Datum transformations as shown in the lower illustration

In some cases you may need to import geospatial data referenced to a coordinate system that does not match any of the predefined choices in the Coordinate Reference System window. You can design and save a custom, private coordinate reference system to match your data. To do so you must select the appropriate projected coordinate system type, select the datum, and define the **map projection** to be used. The exercises on this and the following page provide an example of this procedure. They set up a hypothetical coordinate reference system based on the Transverse Mercator projection for a county in central Nebraska.

- ☑ keep the Coordinate Reference System window open with the current settings and proceed to the next page
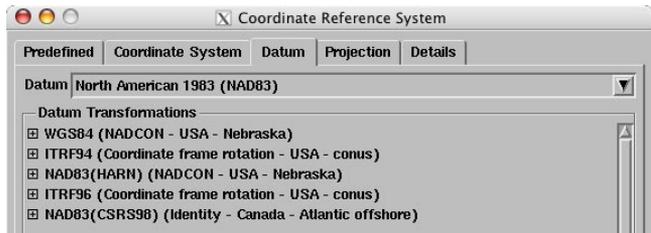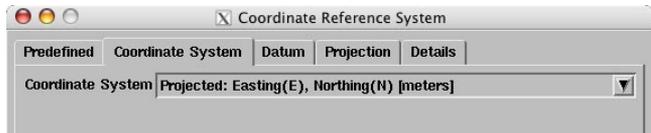
You can save a coordinate reference system for use by the "current user" or for all users (everyone who uses the computer). (One or the other of these choices may be disabled based on permissions set for the directories in which the information needs to be saved.) If you have saved coordinate reference systems for both "current user" and "all users", they are listed under separate subgroups in the Saved group.

Note: To set up a local coordinate reference system that does not require a standard Earth datum (for a construction site, for example), select one of the *Cartesian 2D: X, Y* options from the Coordinate System menu (separate entries for meters and feet are available). Selection of this nonprojected coordinate system automatically sets the datum to *Local engineering*.

Define Projection Parameters

The Projection tabbed panel is active whenever a **projected coordinate system** is in use. The Projection Method menu is automatically activated when you have used the Coordinate System menu to switch from a nonprojected coordinate system (such as Geographic, longitude / latitude) to projected coordinates. If the Projection Method menu is not active when you expose the Projection panel, you can activate it by turning on the User Defined toggle button next to the menu.

Once you have selected the projection method, you can then enter the required projection parameter values in the table on the Projection panel to complete setup of your private coordinate reference system.
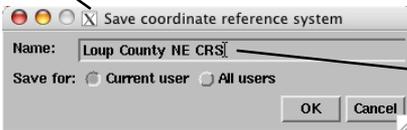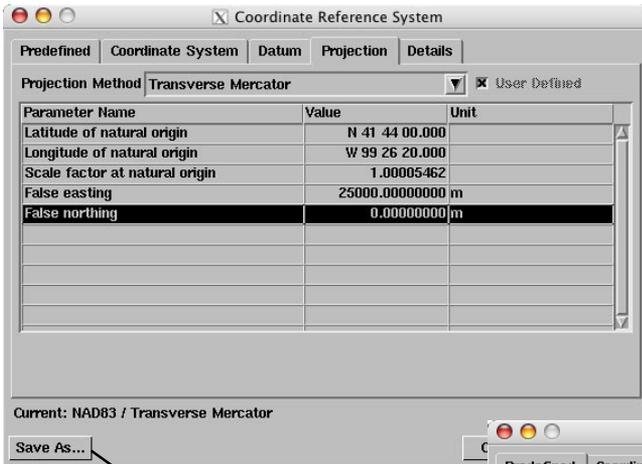
STEPS
☑ click on the Projection tab
☑ from the Projection Method menu, select the first Transverse Mercator entry (NOT the south-oriented entry)
☑ enter the values shown in the box below in the Value fields in the table on the Projection panel

Latitude of natural origin: N 41 44 00.0
Longitude of natural origin: W 99 26 20.0
Scale factor at natural origin: 1.00005462
False easting: 25000.00
False northing: 0.00

☑ press [Save As...]
☑ in the *Save coordinate reference system* window, enter the name Loup County NE CRS and press its OK button
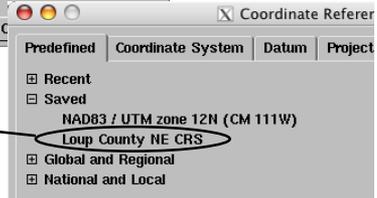

☑ when you have completed this exercise, close the Coordinate Reference System and Map Calculator windows

Change Coordinate Reference System

STEPS
- ☑ select Tools / Change Coordinate Reference System from the TNTmips menu
- ☑ press [Continue] on the Message window
- ☑ in the Select Objects dialog that appears, navigate to the CB_DATA directory and select raster object ELEVATION from the CB_TM Project File
- ☑ if the spatial referencing settings were incorrect, you would use this dialog as in previous exercises to select the correct coordinate reference system.
- ☑ click [Cancel] on the Coordinate Reference System window

The Change Coordinate Reference System utility allows you to correct errors that have been made in setting up the coordinate reference system for a geodata object during georeferencing or import. The process prompts you to select one or more already-georeferenced objects, then opens the standard Coordinate Reference System window. Once you have selected the correct coordinate reference system parameters, clicking [OK] on this window updates the georeference information for each of the selected spatial objects.
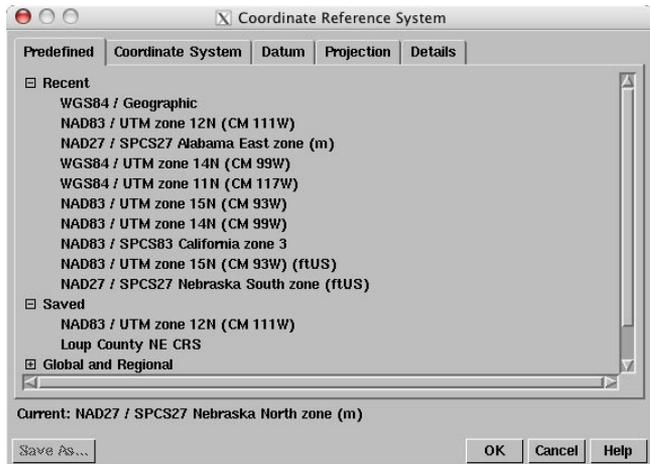
You can also use this utility to resolve problems with the georeference information for external files (TIFF, shapefile, and so on) that you are directly using in TNTmips. In some instances the auto-link operation that detects these files cannot determine their coordinate reference system. This situation is mostly likely to occur with spatial data files accompanied by ArcWorld georeference files. If you can determine the correct coordinate reference system from metadata or other sources, you can use the Change Coordinate Reference System procedure to set the correct information for the auto-linked file.

Spatial Referencing Terminology

The following terms and definitions for spatial referencing concepts and procedures in the TNT Products have been adopted from the ISO standard 19111:2003 entitled *Spatial Referencing by Coordinates*, Section 4, pages 1-5.

Coordinate Reference System: coordinate system that is related to the real world by a datum. (For geodetic and vertical datums, it will be related to the Earth.)

Coordinate System: set of mathematical rules for specifying how coordinates are to be assigned to points.

Cartesian Coordinate System: coordinate system that gives the positions of points relative to *n* mutually perpendicular axes.

Coordinate Conversion: change of coordinates, based on a one-to-one relationship, from one coordinate system to another based on the same datum. Example: between geodetic and Cartesian coordinate systems or between geodetic coordinates and projected coordinates, or change of units such as from radians to degrees or feet to meters. (A coordinate conversion uses parameters that have constant values.)

Coordinate Transformation: change of coordinates from one Coordinate Reference System to another Coordinate Reference System based on a different datum through a one-to-one relationship. (A coordinate transformation uses parameters which are derived empirically by a set of points with known coordinates in both Coordinate Reference Systems.)

Datum: parameter or set of parameters that serve as a reference or basis for the calculation of other parameters. (A datum defines the position of the origin, the scale, and the orientation of the coordinate system.)

Map Projection: coordinate conversion from a geodetic coordinate system to a plane.

Projected Coordinate System: two-dimensional coordinate system resulting from a map projection.

Geodetic Coordinate System or Ellipsoidal Coordinate System: coordinate system in which position is specified by geodetic latitude, geodetic longitude, and (in the three-dimensional case) ellipsoidal height.

Engineering Datum or Local Datum: datum describing the relationship of a coordinate system to a local reference. (Engineering datum excludes both geodetic and vertical datums.) Example: a system for identifying relative positions within a few kilometers of the reference point.

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