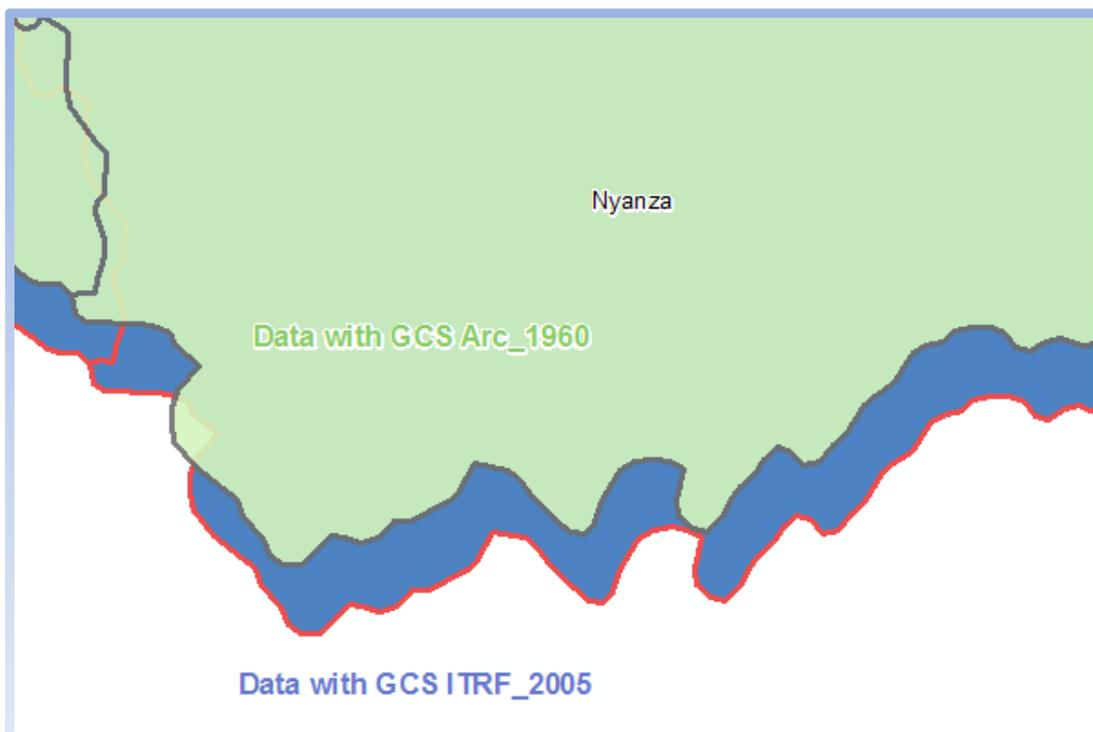


## How to solve the data shift problem in Rwandan Projections

Cook book, Version 0.1  
(under construction)



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# 1 Introduction

The overlay of Rwandan datasets from different sources often leads to a shift of approximately 300m N/S and of approximately 100m E/W (see Titlemap). This has been described by Dr. Werner Flacke from Esri Germany in his book<sup>1</sup>. In Chapter 7.1.2 (attached in the Annex II) he showed the method to transform Geographic Coordinates captured with a GPS using the datum WGS\_1984 so that they fit with data of the Geographic Coordinate System (GCS) Arc\_1960.

The Geographic Coordinate System (GCS) Arc\_1960 is still widely used in Rwanda although there is a strong trend within in the East African Community to move to Geographic Coordinate System (GCS) ITRF\_2005 in the future. The Orthophotos (rectified Aerial Photographs) of the Rwanda Natural Resource Authority - a basis for many projects in Rwanda - are supplied in Transverse Mercator Projection with the Datum parameters in ITRF\_2005.

However there are cases where data will not fit together using the methods described below. Some data have no projection information at all (.prj file) or incorrect projection information or have been captured in a different scale (see Chapter "Other Misfits"). Those cases need to be treated differently: try to get more information from the data owner, try to change parameters or wrap the data (not really recommended).

The following chapters in this cook book will focus on the techniques how to convert the data to have them best fit together.

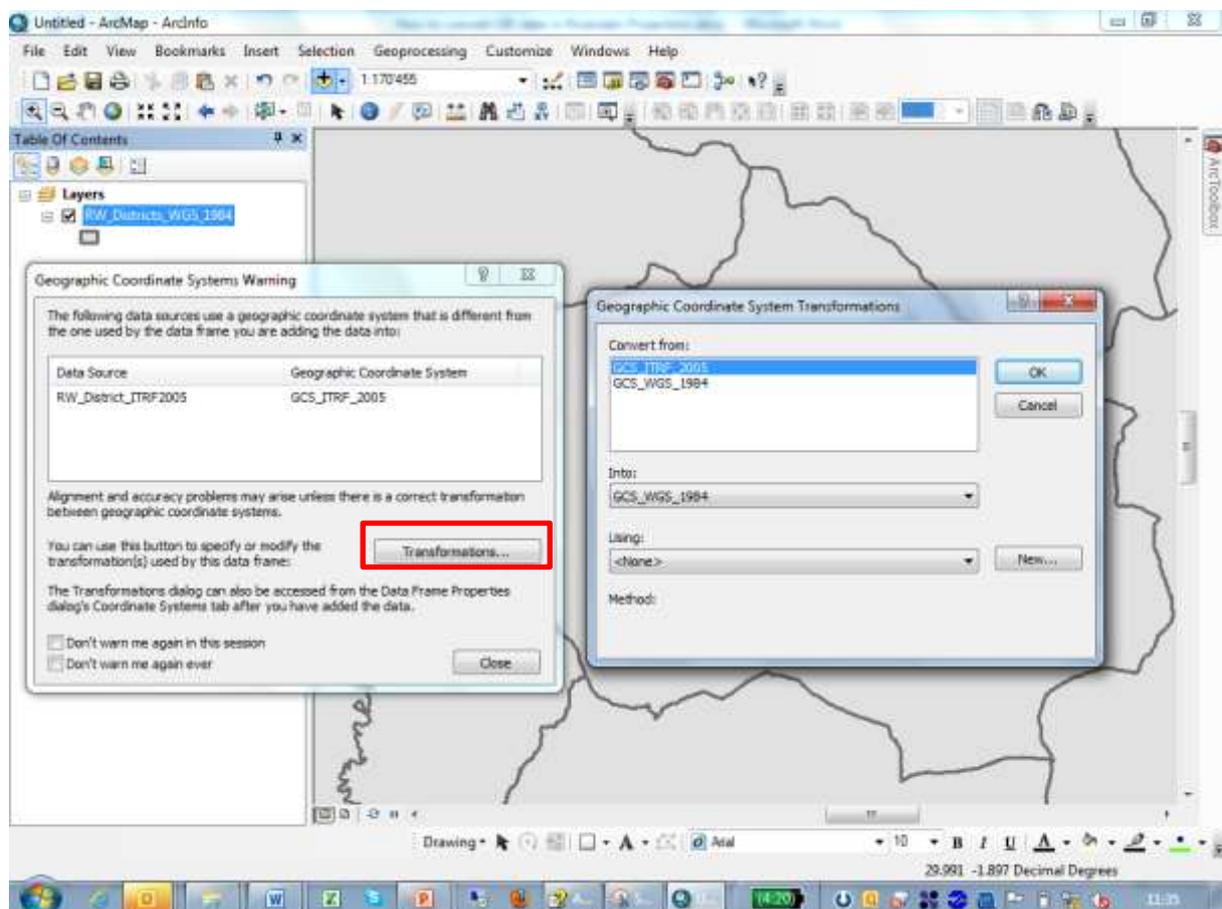
This is a working document. To improve the document Esri Rwanda very much appreciates your feedback. Please send your comments and questions to [info@esri.rw](mailto:info@esri.rw)

## 2 Transformation methods

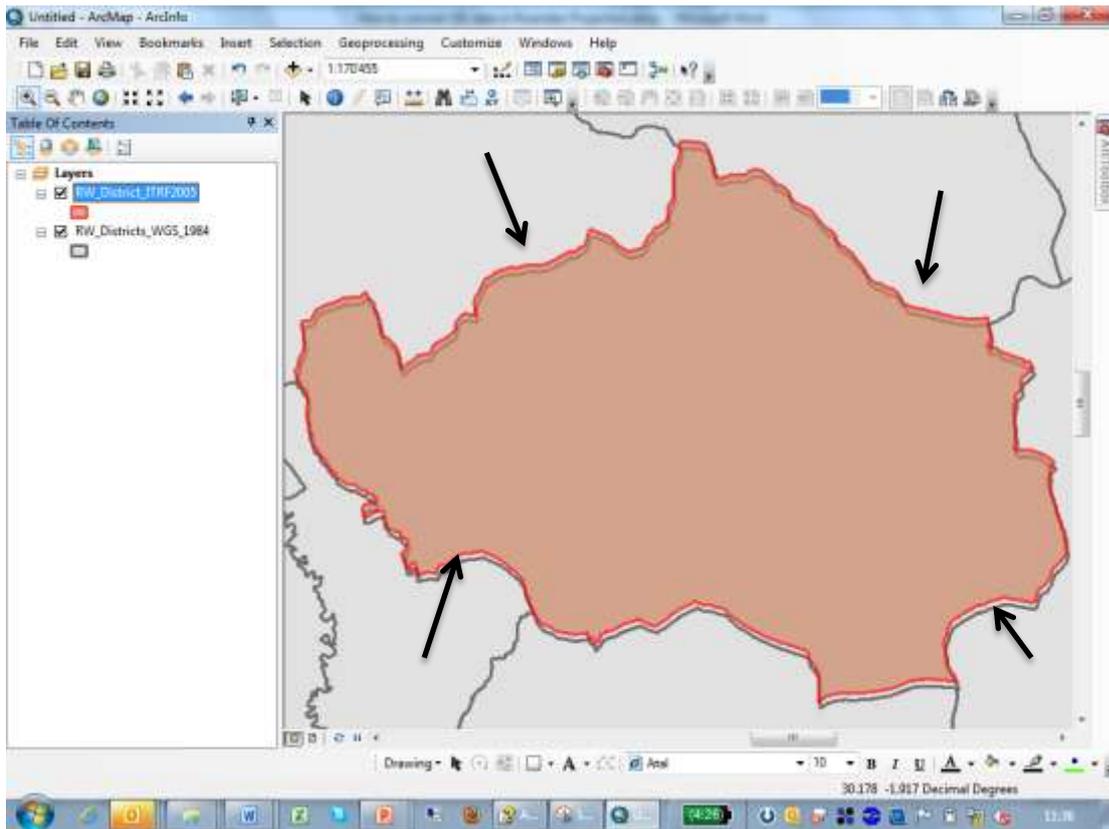
### 2.1 Transformation from Transverse Mercator Projection with GCS ITRF\_2005 to Geographic Coordinates and GCS WGS\_1984

When the original data has a GCS ITRF\_2005 and is supposed to fit to data in WGS\_1984, one needs to transform the data in two steps. However, these steps can be combined into one using the Project tool in ArcGIS Desktop.

Assuming you have a project with a Shapefile of the District of Gasabo in Geographic coordinates and GCS WGS\_1984 and you received new data of the District in Transverse Mercator projection and Datum ITRF\_2005. When you add the new District data (ITRF\_2005) to the existing one (WGS\_1984) ArcMap warns you that a transformation is needed.



After closing the Systems Warning the result looks like this:



Using the Projection Tool you find it under the (ArcToolbox -> Data Management Tools -> Projections and transformations -> Feature -> Project)

Note:

To match the data, one needs to carry out a Geographic Transformation.

Because there is no direct Geographic Transformation from "ITRF\_2005 to WGS\_1984" but there is one from "ITRF\_2005\_to\_IRTF\_2000" and then "ITRF\_2000 to WGS\_1984" we have to use them one after another. Please don't get confused by the names in the transformation dialog. They work in both directions (bi-directional) and are therefore not stored twice in the GIS system.

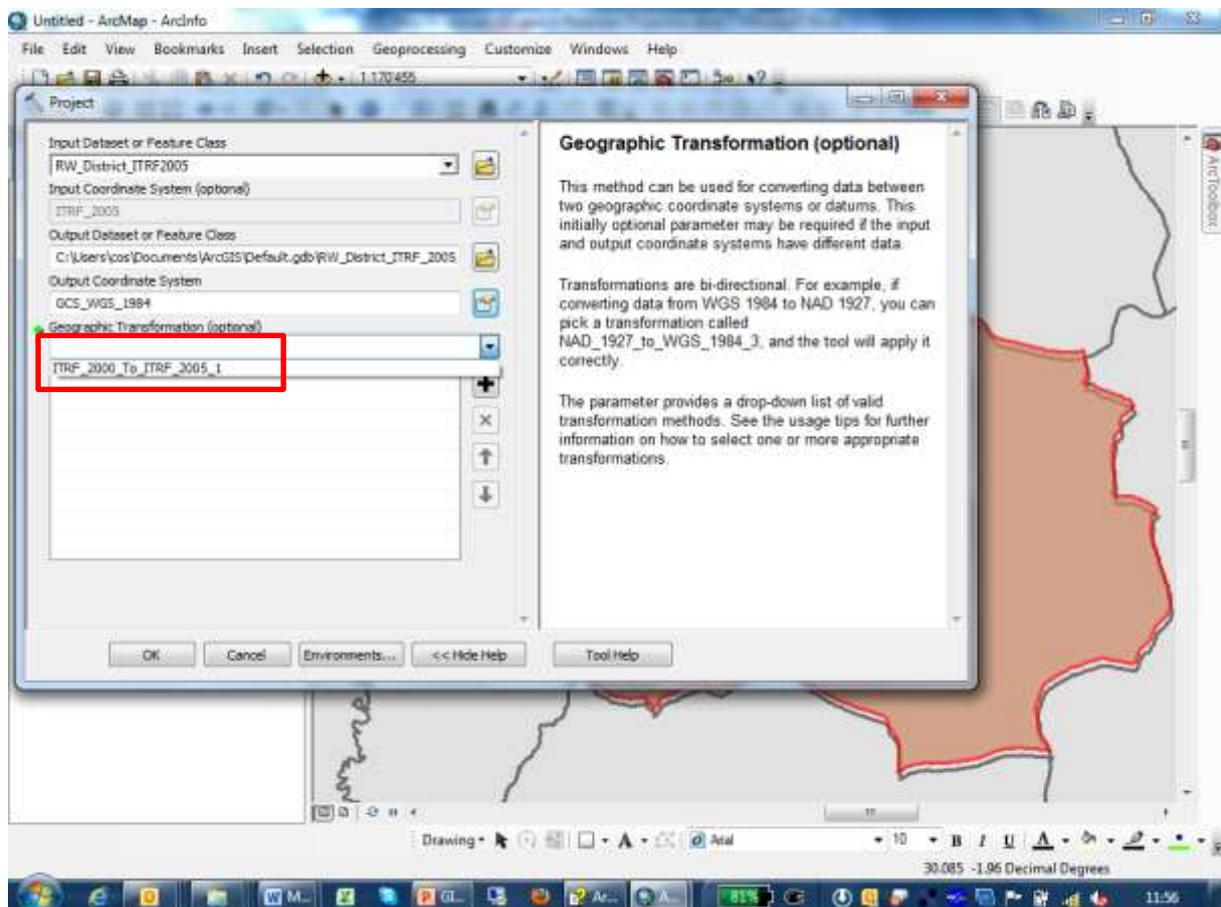
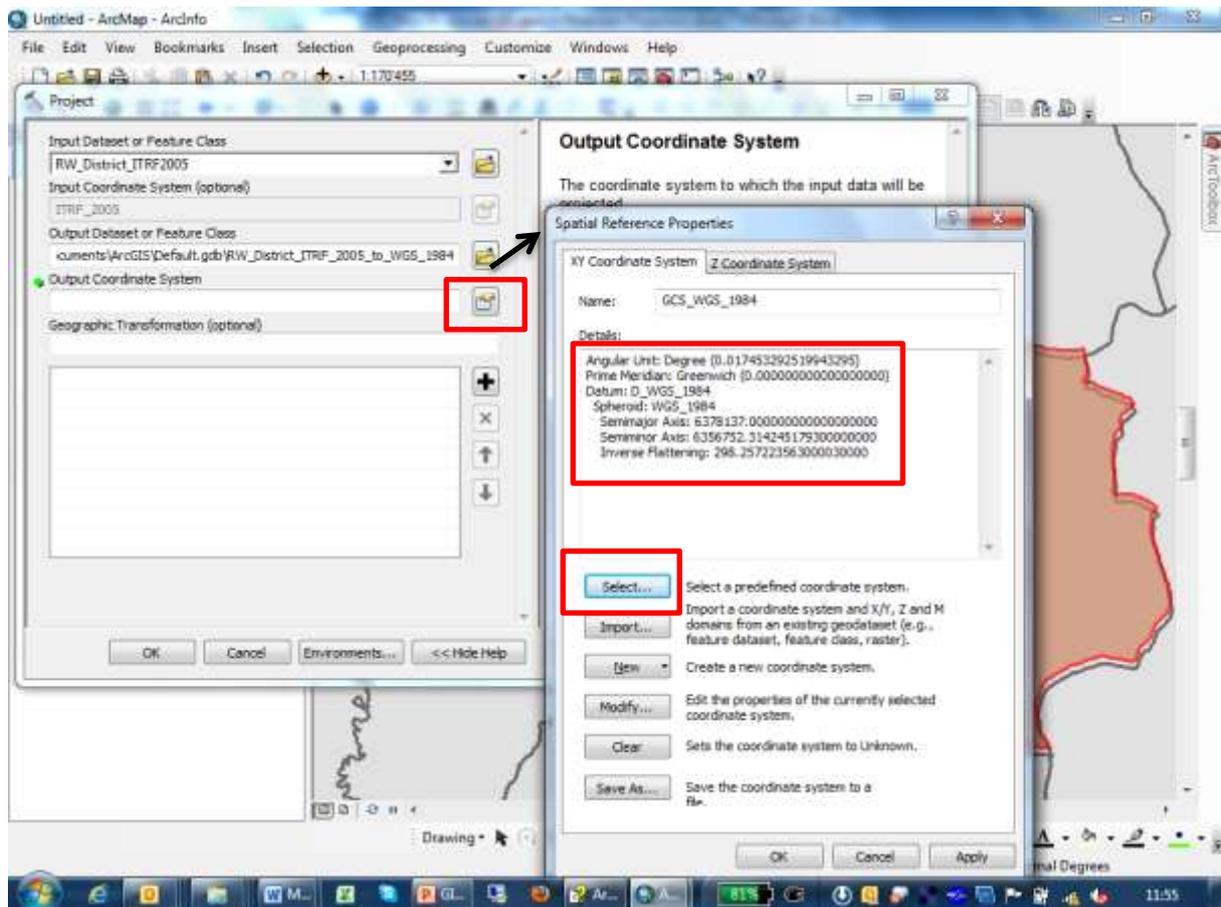
"ITRF\_2005\_1\_To\_IRTF\_2000" using the Geographic Transformation

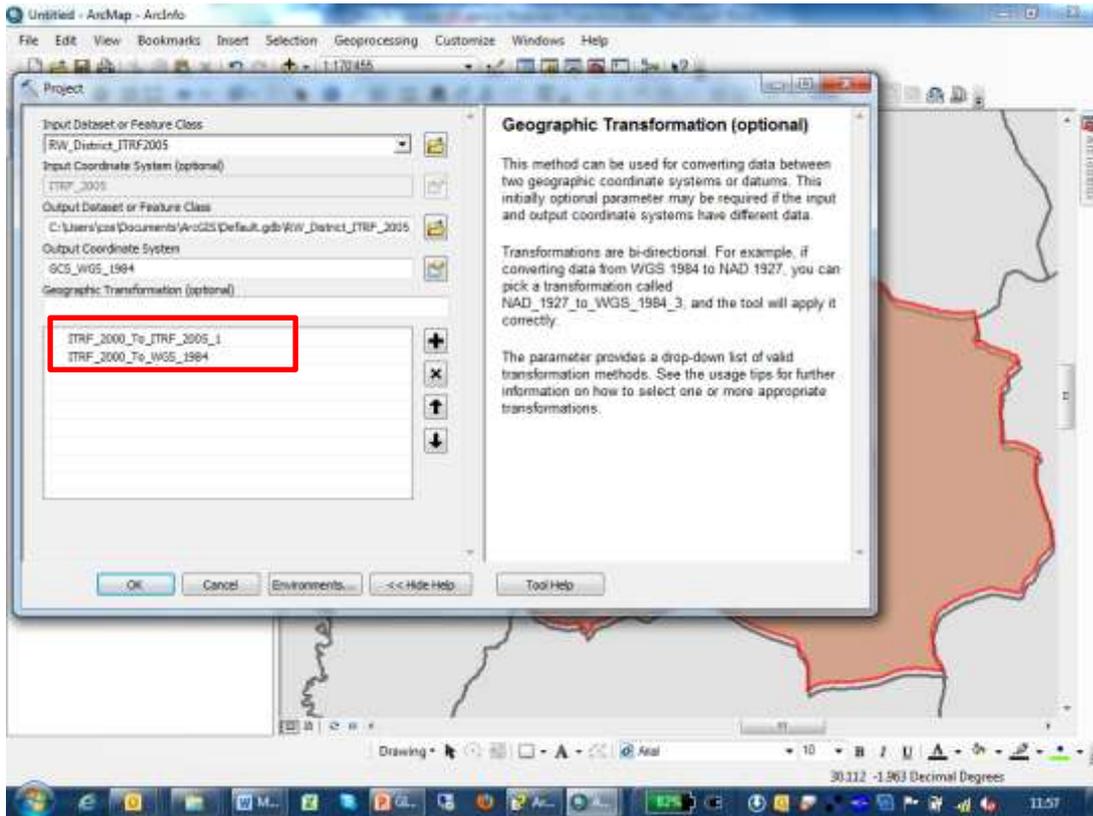
"ITRF\_2000\_To\_IRTF\_2005\_1"

and from

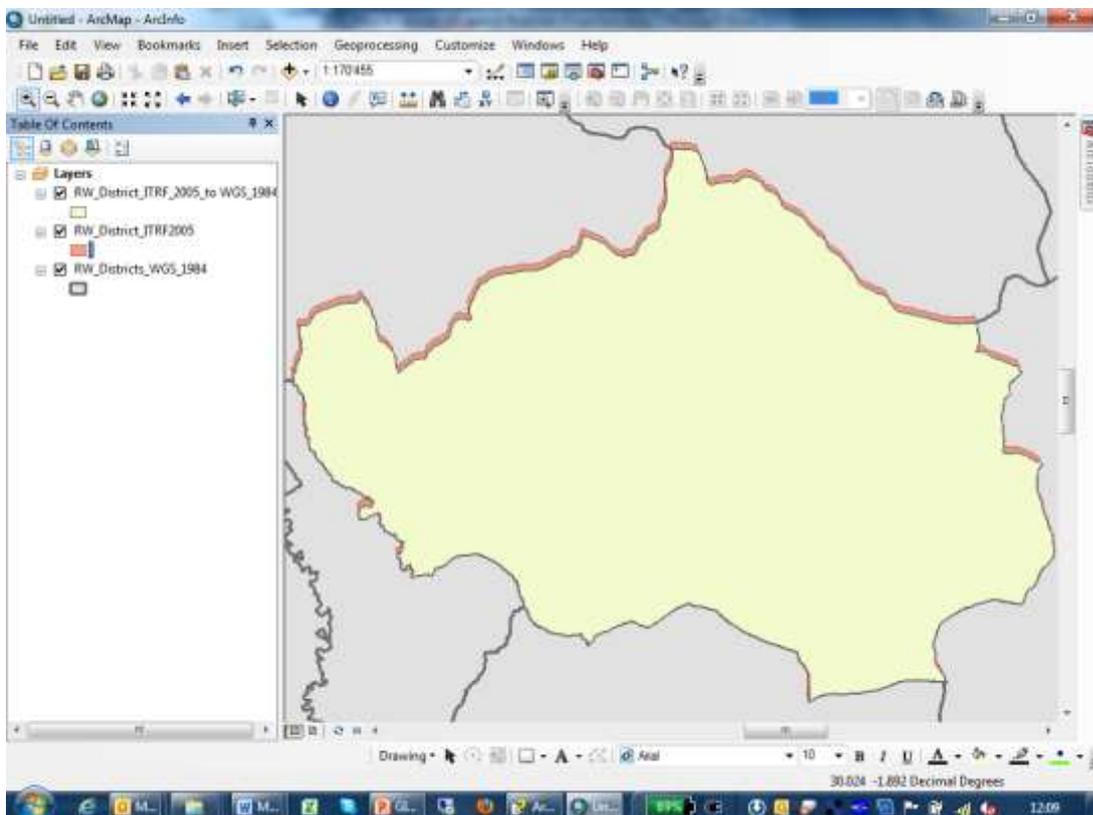
"ITRF\_2000\_To\_WGS\_1984"

The following print screens show step by step what needs to be entered into the Projection Tool.





Now all the parameters have been entered to transform the data.

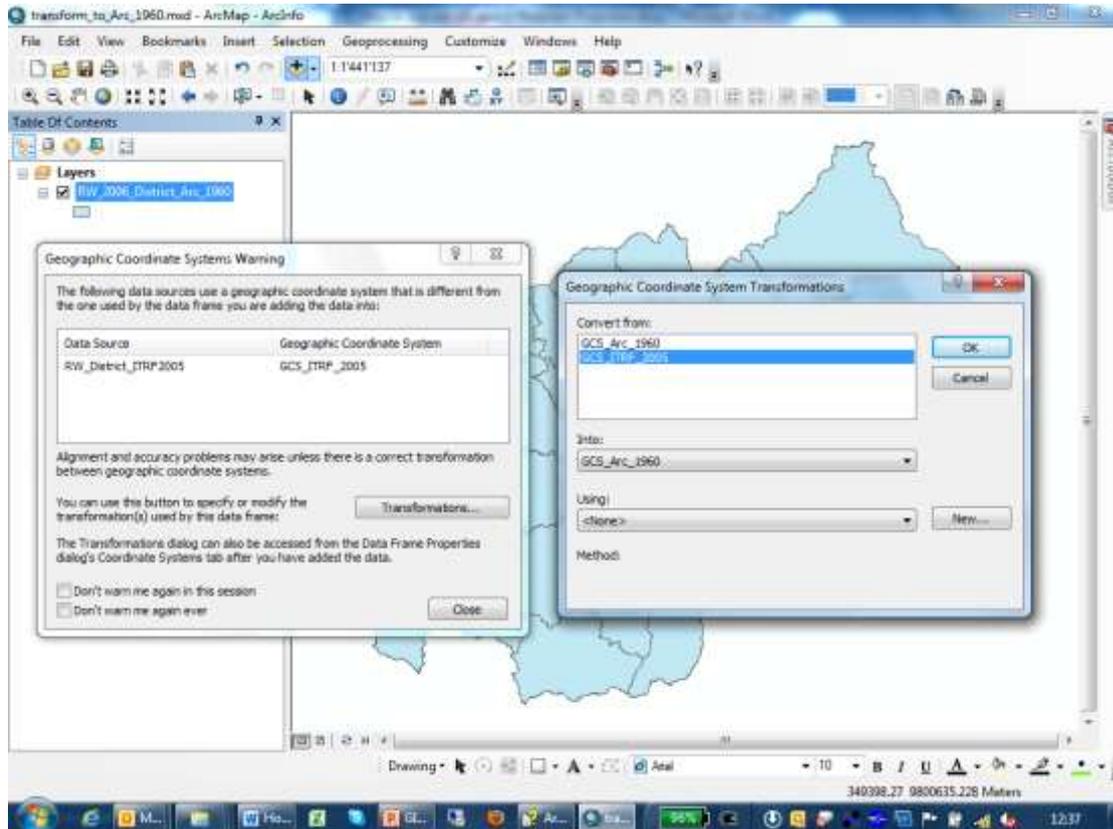


After the Projection and Transformation has been calculated, the District (in yellow) fits exactly to the Shape in WGS\_1984.

## 2.2 Transformation of Transverse Mercator Projection with GCS ITRF\_2005 to Transverse Mercator Projection with GCS Arc\_1960

Another typical case is to transform data in Transverse Mercator Projection with the GCS ITRF\_2005 to Transverse Mercator with GCS Arc\_1960:

The Project and the Shape (RW\_District\_Arc\_1960) are both in GCS Arc\_1960. When you load data in ITRF\_2005 you are asked to specify the GCS of the shapefile.



Using the Projection Tool (ArcToolbox -> Data Management Tools -> Projections and transformations -> Feature -> Project)

This Projection requires one more Transformation steps than the previous one. In this case we go from

“ITRF\_2005\_1\_To\_ITRF\_2000” using the Geographic Transformation

“ITRF\_2000\_To\_IRTF\_2005\_1”

than from

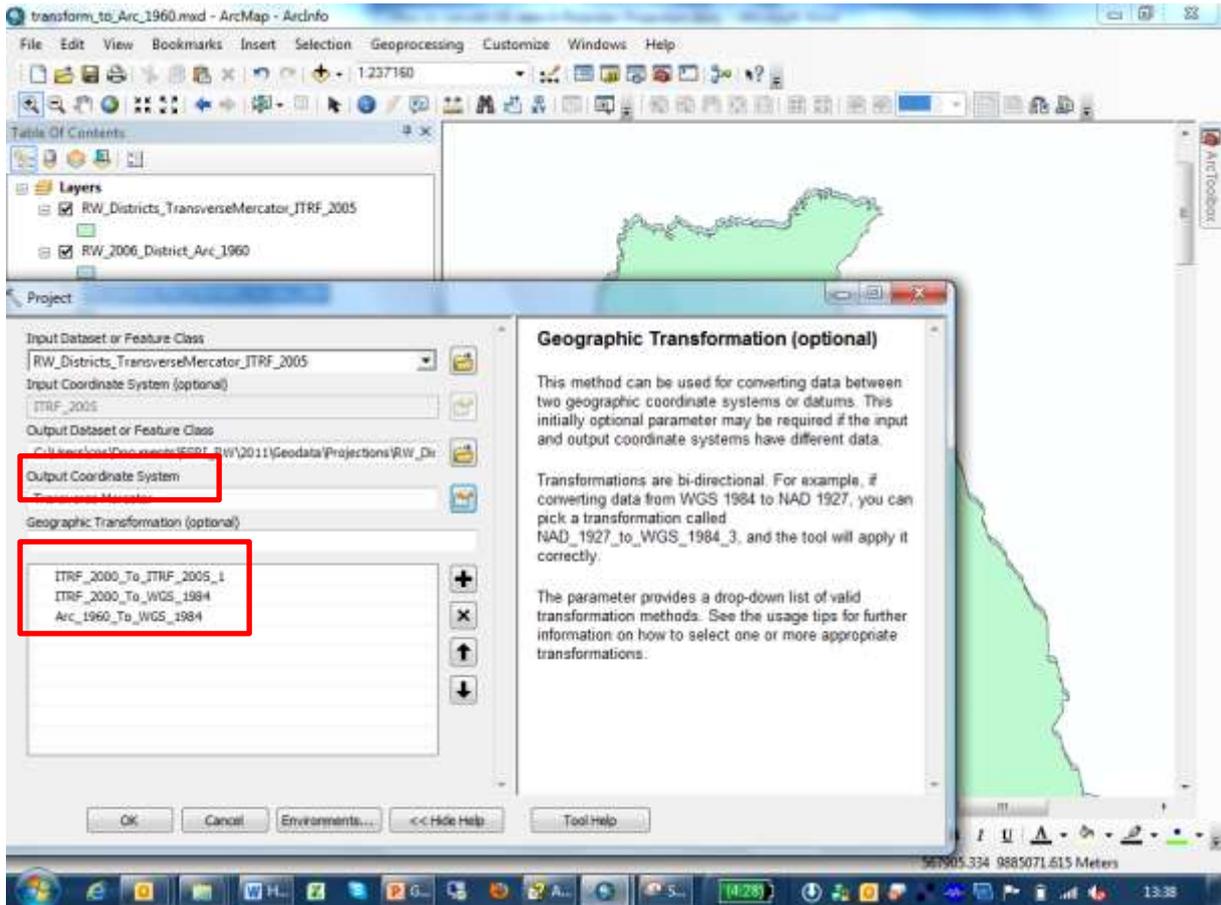
“ITRF\_2000\_To\_WGS\_1984” using the Geographic Transformation

“ITRF\_2000\_To\_WGS\_1984”

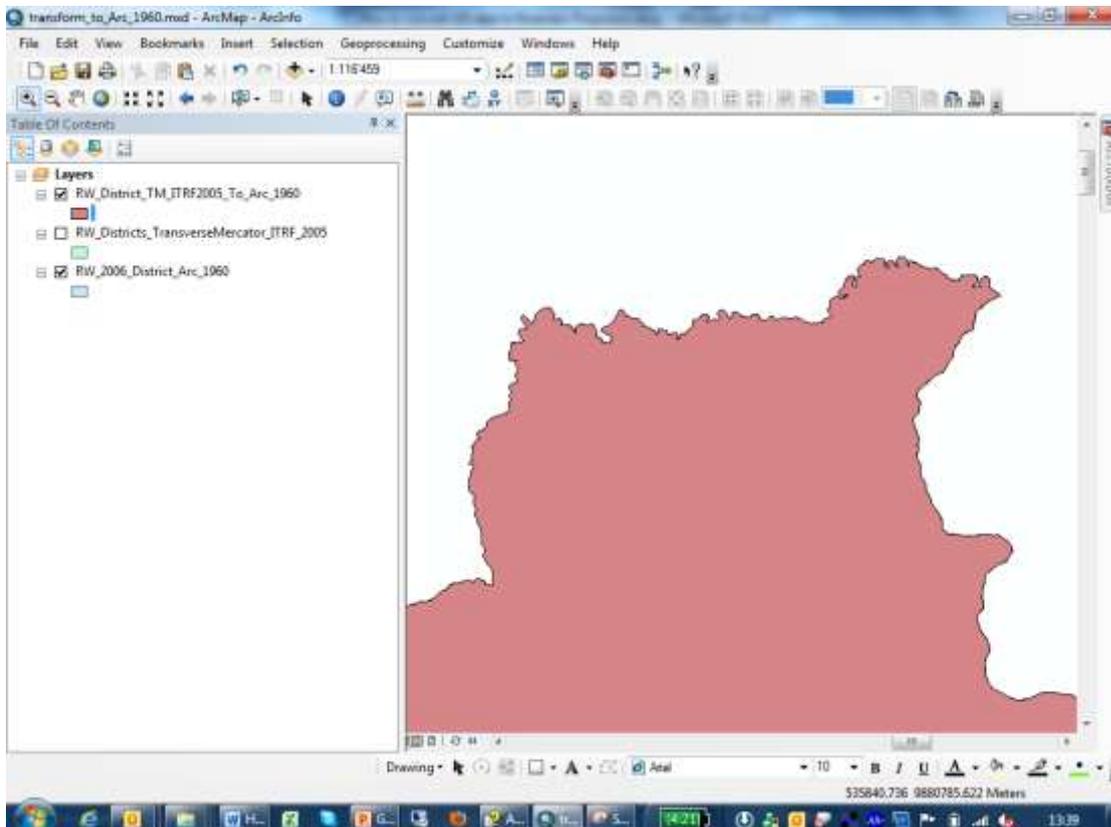
than from

“WGS\_1984\_To\_Arc\_1960” using the Geographic Transformation “Arc\_1960\_To\_WGS\_1984

The following print screens show step by step what needs to be entered into the Projection Tool.



Perfect fit after Projection



### 3 Other misfits

Please keep in mind that there will always be a misfit if data are collected at different scales. One good example is the Road data from 1988 which were digitized from the Rwandan Topographic Maps in a scale of 1:50'000. When they are overlaid on top of an Orthophoto (with courtesy of RNRA) with a raster cell resolution of 25 cm it cannot and will never fit perfectly. One might face distances up to 40m when one zooms beyond the scale of 1:25'000. (see the lower right image below in a scale of 1:5'000)



## 4 Tips and tricks

### 4.1 GPS data collection in the field

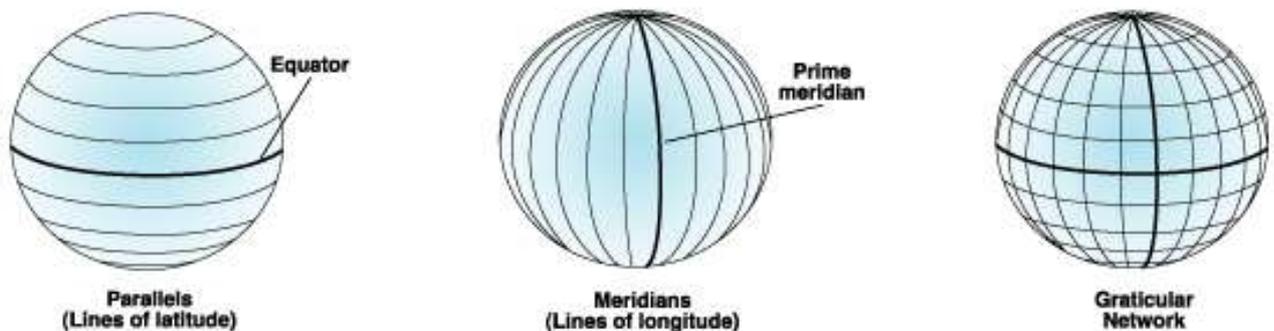
You can avoid future data misfits and a lot of post processing work when you determine the Datum or the Geographic Coordinate System already in your GPS **before** going to the field. Depending on your reference data you have in your GIS system you should set the same reference in your GPS. Not all GPS devices have the Arc\_1960 Datum stored; in this case it is safe to use WGS\_1984 which can easily be converted later on to your reference system on your computer using the methods described above. If you will provide field data captured with GPS to external parties, it is recommended to capture the data in Geographic Coordinates and the GCS WGS\_1984. It is very easy to convert them later on into any other Projection and Geographic Coordinate Systems.

# 5 Terms

## 5.1 Geographic Coordinate System (GCS ) or Datum

A geographic coordinate system (GCS) uses a three-dimensional spherical surface to define locations on the earth. A GCS includes an angular unit of measure, a prime meridian, and a datum (based on a spheroid).

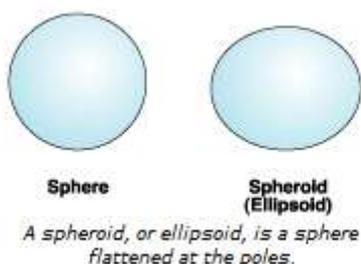
A point is referenced by its longitude and latitude values. Longitude and latitude are angles measured from the earth's centre to a point on the earth's surface. The angles often are measured in degrees (or in grads). The following illustrations show the world as a globe with longitude and latitude values.



Defines the position of the spheroid relative to the centre of the earth. A datum provides a frame of reference for measuring locations on the surface of the earth. It defines the origin and orientation of latitude and longitude lines.

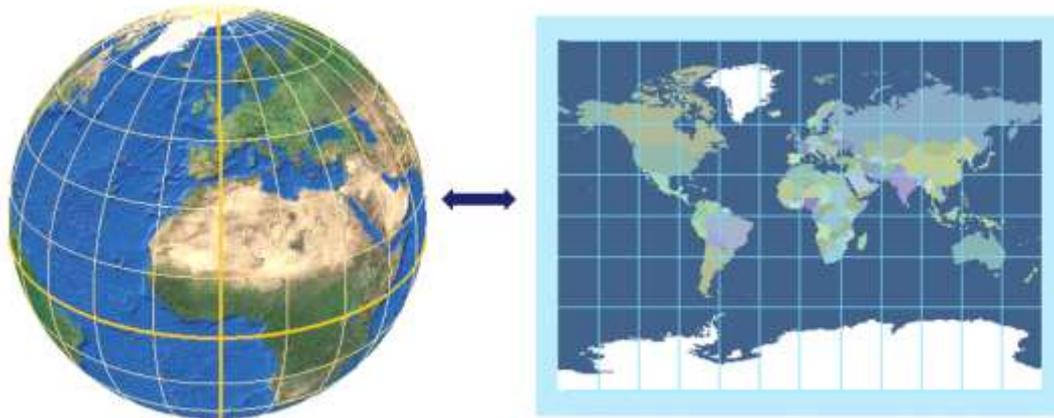
The terms geographic coordinate system and datum are often used interchangeably. But a datum is only one part of a GCS and datum is an older term. The concept of a datum is included within a geographic coordinate system.

## 5.2 Spheroid approximates the shape of the earth



## 5.3 Projections

Are mathematical formulas to relate spherical coordinates on the globe to flat, planar coordinates.



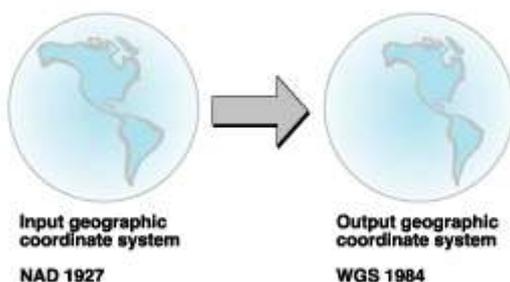
## 5.4 Transformation:

Moving data between coordinate systems sometimes includes transforming between the geographic coordinate systems.

## 5.5 Geographic transformation methods

(from ArcGIS 10 Help)

Moving your data between coordinate systems sometimes includes transforming between the geographic coordinate systems.



Because geographic coordinate systems contain datum that are based on spheroids, a geographic transformation also changes the underlying spheroid. There are several methods, which have different levels of accuracy and ranges, for transforming between datum. The accuracy of a particular transformation can range from centimeters to meters depending on the method and the quality and number of control points available to define the transformation parameters.

A geographic transformation is always defined in a particular direction. The picture above illustrates a transformation that converts from North American Datum (NAD) 1927 to World Geodetic System (WGS) 1984. When working with geographic transformations, if no mention

is made of the direction, an application or tool like ArcMap will handle the directionality automatically. For example, if converting data from WGS 1984 to NAD 1927, you can pick a transformation called NAD\_1927\_to\_WGS\_1984\_3 and the software will apply it correctly.

## 6 Literature

<sup>1</sup>Werner Flacke/Birgit Kraus, 2005: Working with Projections and Datum Transformations in ArcGIS, Theory and Practical Examples, Points Verlag Norden – Halmsted. ISBN 3-9808463-5-0

ArcGIS Desktop 10 Help

## 7 Appendix I

### 7.1 Parameters for Arc\_1960

Projected Coordinate System: Transverse Mercator  
Projection: Transverse\_Mercator  
False\_Easting: 500000.00000000  
False\_Northing: 10000000.00000000  
Central\_Meridian: 30.00000000  
Scale\_Factor: 0.99990000  
Latitude\_Of\_Origin: 0.00000000  
Linear Unit: Meter (1.000000)

Geographic Coordinate System: GCS\_Arc\_1960  
Datum: D\_Arc\_1960  
Prime Meridian: Greenwich  
Angular Unit: Degree

### 7.2 Parameters for ITRF\_2005

Projection: Transverse\_Mercator  
False\_Easting: 500000.000000  
False\_Northing: 5000000.000000  
Central\_Meridian: 30.000000  
Scale\_Factor: 0.999900  
Latitude\_Of\_Origin: 0.000000  
Linear Unit: Meter (1.000000)

Geographic Coordinate System: GCS\_ITRF\_2005  
Datum: D\_ITRF\_2005  
Prime Meridian: Greenwich  
Angular Unit: Degree

## 8 Appendix II

### Working with Projections and Datum Transformations in ArcGIS Theory and Practical Examples

Dr. Werner Flacke / Birgit Kraus  
Points Verlag Norden Halmstad  
ISBN 978-3-9808463-5-6  
360 Pages, richly illustrated, paperback, June 2005

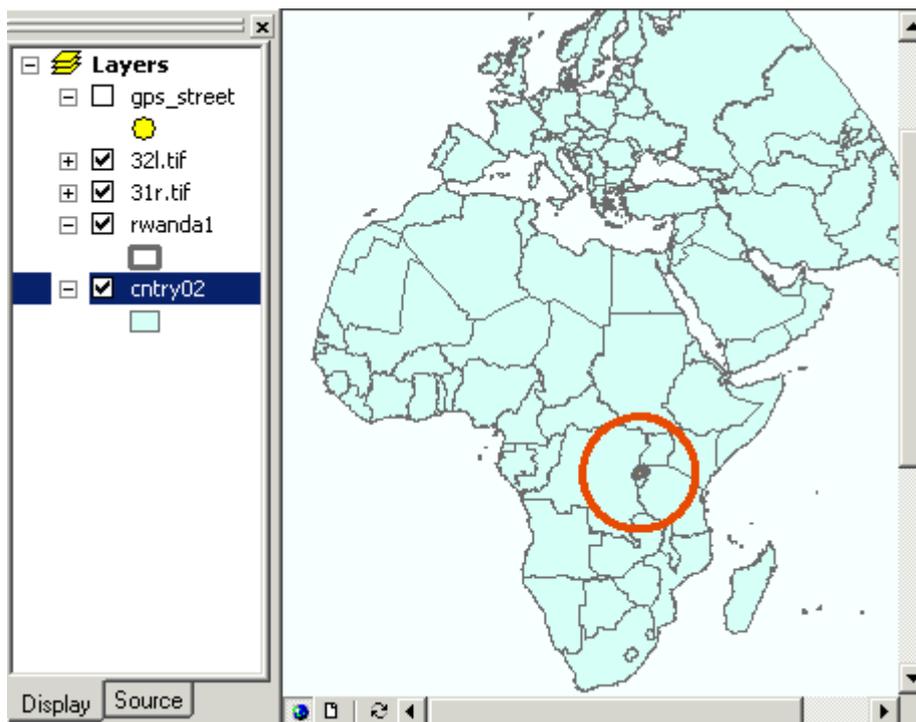
*An invaluable aid for ArcGIS users: This book contains an ideal mix of background information on projections and transformations together with detailed explanations of their usage in ArcGIS.*

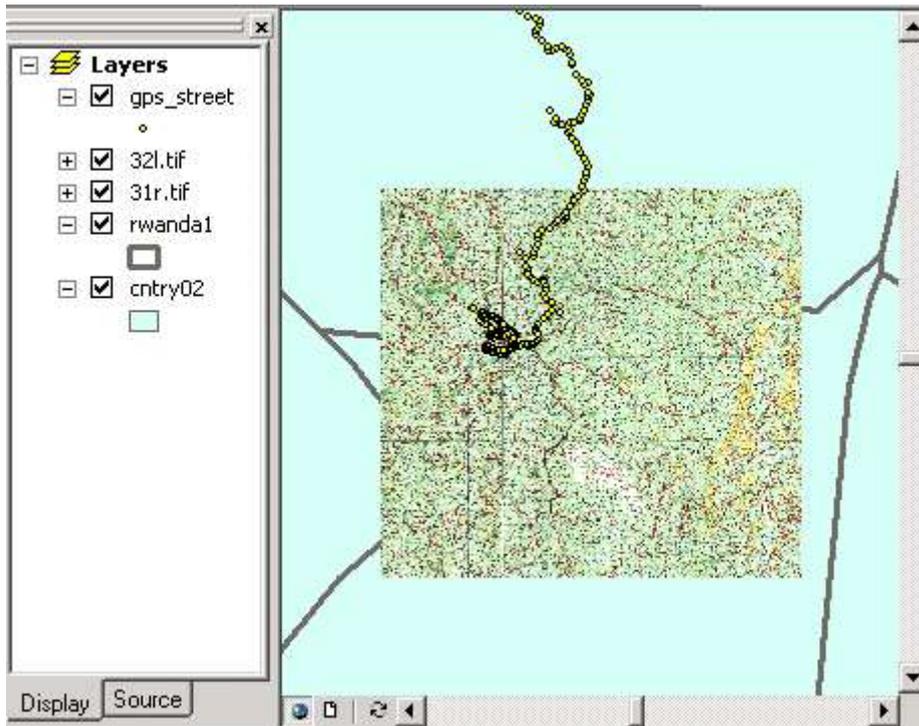
See <http://www.pointsverlag.de/main.php?points=verl&page=buecher&kat=2> or amazon.

#### Chapter 7.1.2 GPS data (WGS\_1984) on a map from Rwanda (Arc\_1960)

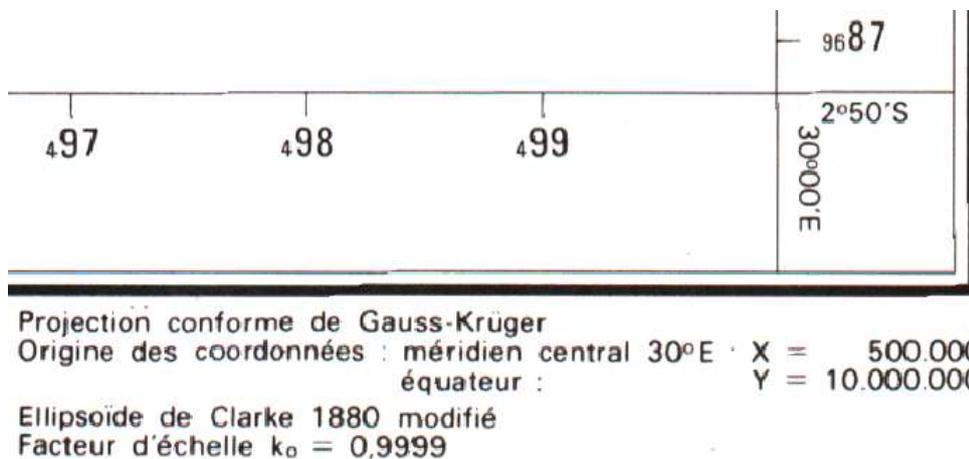
Let us take a trip to Rwanda. There we encounter a CRS which is not predefined and which gives us plenty of opportunity to investigate the various aids available for defining and then implementing the correct coordinate system.

Rwanda is one of the smallest countries in Africa. We have maps of a part of it at a scale of 1:50,000 and GPS coordinates registered on our arrival.





It is a fair guess that you have never had to deal with a coordinate system in Rwanda before. Therefore we will not confine ourselves to discussing the steps involved in ArcMap, but also recapitulate how the necessary background information can be gathered. The legend of the raster map contains the following information relating to the coordinate system used:



'Gauss-Krüger' has a familiar ring to it (synonymous to 'Transverse Mercator'). The central meridian is 30° with a scale factor of 0.9999. The false easting is 500,000, whilst the false northing is 10,000,000 (as is usual in the southern hemisphere). The modified Clarke ellipsoid from 1880 is used.

This information is sufficient to identify the projection and its parameters unambiguously. Now we can look for the associated GCS. The folder Geographic Coordinate Systems \ Africa contains 71 GCS, including a number of variants for Clarke 1880 'modified' (Clarke\_1880\_IGN, Clarke\_1880\_RGS, Clarke\_1880\_Arc). Therefore we need an even more detailed classification at country level. This is available in ArcGIS Desktop Help > Map Projections > An overview of map projections > Link: Learn more about supported geographic coordinate systems. Unfortunately, Rwanda does not appear here,

so we have to investigate neighboring countries. For Tanzania we have the PCS Arc\_1960\_UTM\_Zone\_35S and the transformation Arc\_1960\_To\_WGS\_1984\_3, with its reference to the Arc\_1960 datum. Burundi is associated with the transformation Arc\_1950\_To\_WGS\_1984\_3, Uganda to the PCS Arc\_1960\_UTM\_Zone\_35N. Thus there are two possible datums, D\_Arc\_1950 and D\_Arc\_1960. In turn, these are associated with the ellipsoids Clarke\_1880\_Arc and Clarke\_1880\_RGS, both of which fulfill the criterion 'modified'. We choose D\_Arc\_1960 and Arc\_1960\_To\_WGS\_1984. This has to remain a guess, but the candidates differ only slightly.

Here is a summary of the information which we have gathered using the research above as well as the file geographic\_transformations.pdf (map\_projection\_tables.pdf in ArcGIS 8.3) and relevant PRJ files:

DATUM["D\_Arc\_1960",SPHEROID["Clarke\_1880\_RGS",6378249.145,293.465]]

Arc\_1960\_To\_WGS\_1984 Geocentric Translation -160 -6 -302 Kenya, Tanzania

Arc\_1960\_To\_WGS\_1984\_3 Geocentric Translation -175 -23 -303 Tanzania

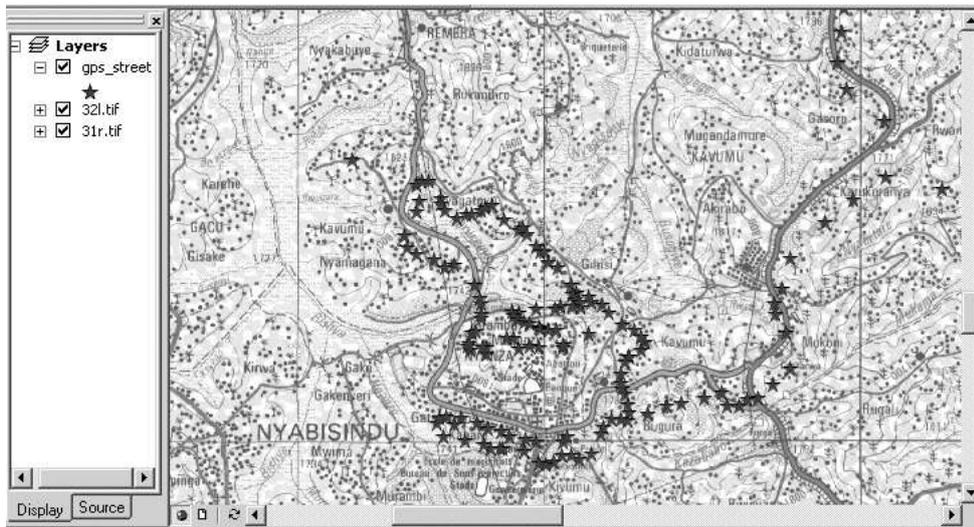
DATUM["D\_Arc\_1950",SPHEROID["Clarke\_1880\_Arc",6378249.145,293.466307656]]

Arc\_1950\_To\_WGS\_1984\_1 Geocentric Translation -143 -90 -294 Zaire

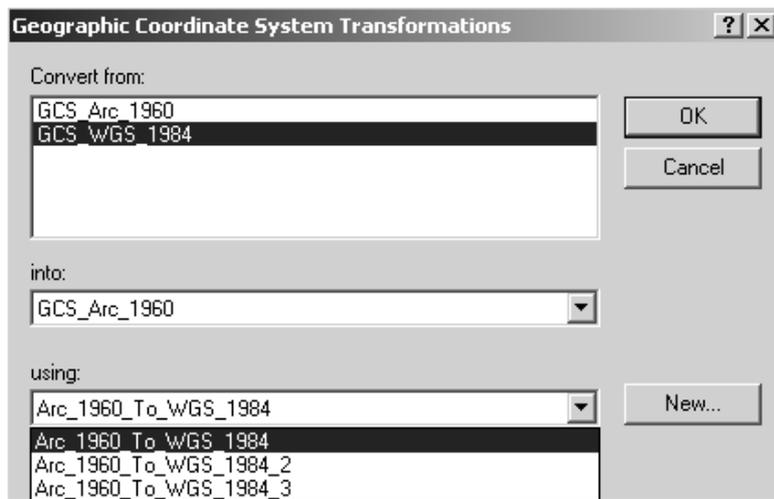
Arc\_1950\_To\_WGS\_1984\_3 Geocentric Translation -153 -5 -292 Burundi

Now we have all the data which we need in order to define the CRS of the raster maps. These we load into ArcMap first, followed by the shapefile of the GPS points.

Object	CRS layer GCS layer	Transformation	Data frame CRS Data frame GCS
Data frame and raster maps			Transverse Mercator Arc_1960
GPS shapefile	GCS_WGS_19 84		
		Arc_1960_To_WGS_19 84	



A warning is issued which we ignore at first. Not unexpectedly, the GPS points appear with a distinct shift in respect of the roads which they were obviously supposed to represent. The shift is about 300 m.



After setting the transformations a good fit is achieved.

