

Editor's Note

This is the last issue of the GPS Newsletters. After 3 1/2 years of GPS Newsletters we have decided to discontinue our regular newsletters. System500 and SKI-Pro have been covered in detail and we believe we have created a solid base of information for users to delve into.

Country Specific Coordinate System Models

This newsletter focuses on a simple and efficient way to transform between WGS84 and local coordinates – the **Country Specific Co-ordinate System (CSCS) Models**. Within System 500 a co-ordinate system is the definition of how coordinates are converted between **WGS84** and **Local Grid**. Different methods are supported by SKI-Pro and by the sensor (see also Newsletters Vol. 01, No. 08, Vol. 01, No. 09 and 18). The most common approach is to define a Classical 3D Helmert transformation together with the local reference ellipsoid and the local map projection. Please refer back to Newsletters Vol. 00, No. 20 and 21 for the basics of coordinate conversions.

Why transform?

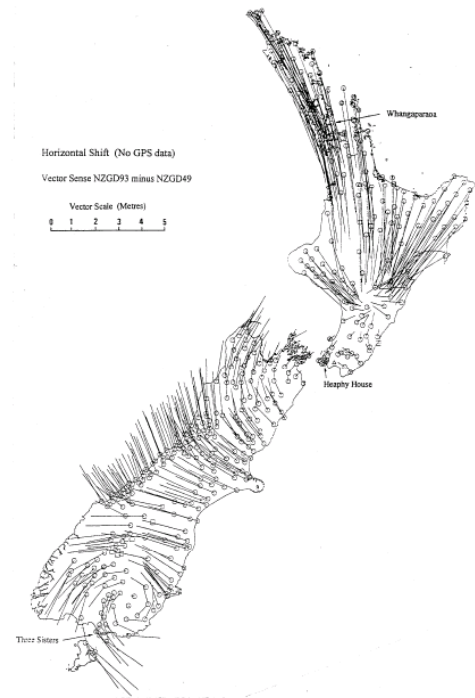
What exactly is the reason why coordinates measured with GPS have to be transformed when wishing to view these in a local grid system? The most obvious reason is the fact that all coordinates derived from GPS are given in the WGS 1984 System. They can be related to the WGS84 ellipsoid, whereas the local coordinates are typically defined with respect to a map projection on a local ellipsoid, which is different in its dimensions, origin and orientation. This fact is often referred to as the local datum of the grid system.

However, this is not the only reason why transformations have to be established each time when working with GPS. To take the datum of the local reference ellipsoid into account, one set of Classical 3D transformation parameters would be enough for each country. Unfortunately this is not possible because the local control coordinates are typically based on measurements and calculations from decades ago, and therefore show distortions due to the propagation of errors when calculating the higher order triangulation networks. These distortions may amount to up to several meters throughout even small countries. Therefore transformation parameters have to be calculated separately for each area of interest.

The distortions of the local mapping systems cannot be described with one set of 7 transformation parameters for one country, but they show a systematic behaviour when looking at greater areas. This fact allows interpolating the

distortions in a grid file, if they are given for the entire country or region of interest. And this is exactly what CSCS models are doing! Once the distortion values are given, you can always transform between WGS84 and local coordinates without having to calculate your own set of transformation parameters. A tabulated lookup-table of the distortion values is used instead.

The picture below shows the distortion vectors of the New Zealand CSCS Model.



Three different types of CSCS Models

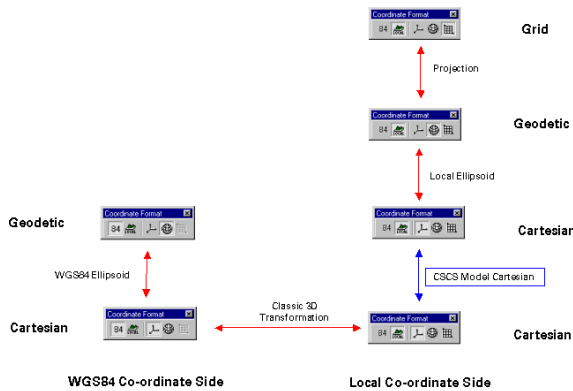
A CSCS Model is an addition to an already defined Coordinate System, which applies correction values in addition to the standard conversion routines (transformation, ellipsoid, map projection). Depending on the step, at which the correction is applied, System 500 supports three different types of CSCS Models.

Cartesian CSCS Models

Imagine that for a set of points you have local grid coordinates and WGS84 coordinates in a specified reference frame. You could then calculate Local Cartesian and WGS84 Cartesian coordinates for all these points and build the difference dX , dY , dZ for all of them. If the points are close enough, you will see a systematic trend in these shifts over your country.

A **Cartesian CSCS model** is a lookup table of Cartesian shift vectors given at a regular grid. The density of the grid must be small enough to allow interpolating the correction value for any point in between the grid nodes.

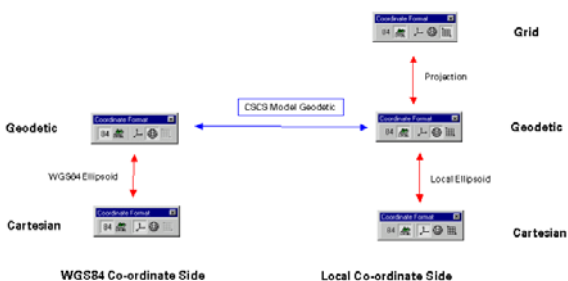
When a Cartesian CSCS model is to be applied, the local grid coordinates are computed as shown below. After an optional transformation, the interpolated shift vector is applied yielding the Local Cartesian coordinates, which are converted to local grid using the local ellipsoid and the local map projection.



Geodetic CSCS Models

Geodetic CSCS Models work quite similar to the Cartesian ones. Such models are lookup-tables comprising of the differences in latitude and longitude on the WGS84 and the local ellipsoid. Again the tabulated differences include the datum of the local ellipsoid and the distortions of the local mapping system.

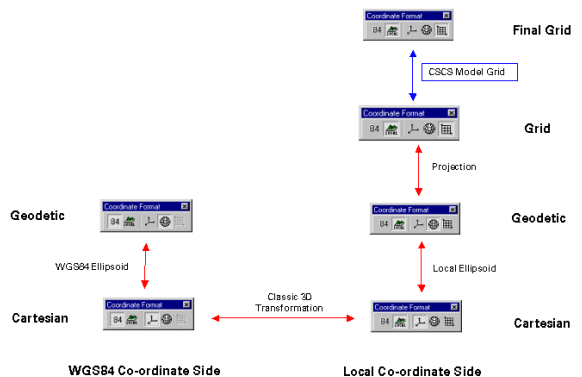
When a Geodetic CSCS Model is to be applied, the local grid coordinates are computed as shown below. The interpolated shift in latitude and longitude is applied to the WGS84 Geodetic coordinates yielding the Local Geodetic coordinates onto which the map projection is applied to get to local grid. Note that a transformation is not allowed as part of the Coordinate System definition, as otherwise there would be two ways of getting to local coordinates.



Grid CSCS Models

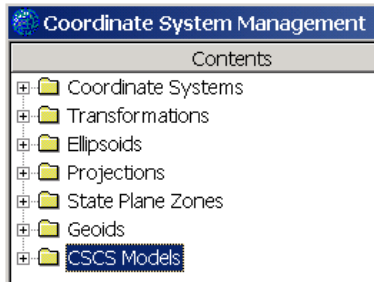
This is the most commonly used CSCS model type today. Many countries are currently establishing new mapping systems based upon undistorted measurements as they are derived from GPS. If you compare these “new” undistorted grid coordinates with the existing ones, you can plot the differences, and again you will typically see a systematic trend. Even if the new mapping systems become official, surveyors will still need to stake out points given in the “old” system. **Grid CSCS Models** do the task of switching between the two.

A Grid CSCS Model is a lookup-table consisting of shifts in Easting and Northing tabulated at a regular grid. When a Grid CSCS Model is to be applied, the local grid coordinates are computed as shown below. After applying an optional Classical 3D transformation, the coordinates are converted to grid using the local ellipsoid and the local map projection yielding preliminary grid coordinates. Then the correction values are interpolated and added, which results in the final grid coordinates.



CSCS Models in SKI-Pro

CSCS Models have to be defined in SKI-Pro’s **Coordinate System Management**. Some models are already pre-defined after the installation of SKI-Pro. New models can be added, if a CSCS Model file is available in the binary System 500 CSC-File-Structure (see later a comment how to obtain such files).



Once the CSCS Model is defined it can be used as part of a Coordinate System. Whenever coordinates are converted between WGS84 and Local, the CSCS Model is automatically invoked, the correction value is interpolated, and the conversion is done without any additional user interaction. Simple!

CSCS Models on System 500 Sensors

The System 500 Sensor firmware uses exactly the same file structure as SKI-Pro. CSCS Models can be accessed from the **System Memory** or from the **PC-Card**. Copy the CSC-file to the \DATA\GPS\CSCS folder of your card and press F2=PCARD to access the CSCS models from the PC-Card.



SKI-Pro allows the creation of **CSCS field files**, if files with limited extents (and therefore smaller file size) are required.

As soon as the CSCS model is part of the coordinate system it is automatically taken into account every time you wish to convert coordinates. Just as in SKI-Pro. Just as simple!

What about heights?

CSCS models contain correction values, which account for the plane distortions in your mapping system. With Grid and Geodetic models this is obvious, but even with Cartesian models you will typically not get directly to orthometric heights. However, all types of CSCS models can be combined with **Geoid models** based on either WGS84 or Local coordinates to derive **orthometric heights**.

The benefits

The big benefit of using a CSCS model is that you do not have to care about calculating your transformation parameters separately for each

project. You measure with GPS and you are immediately tied into the local mapping system. The only, but important, condition is that you cannot just start from any WGS84 coordinates at your reference (like, for example, a HERE position), but you must be related to the same reference frame, based upon which CSCS model was established.

Create your own CSCS Model?

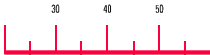
Are you interested in taking this advantage? Probably yes, but you may argue that CSCS models are something you have to wait for until official government authorities provide all the necessary data. While it is true, that surveying agencies around the world have started to communicate the distortion values across their countries, you may even want to set up your own CSCS model independently.

The following is just one example: Imagine you are working in a larger area like a township, where otherwise you have to use several different transformation sets, always having to make sure you pick the right one. You can simply set up a CSCS model instead.

All you need to define is the distortions at a regular grid. First be certain about which approach to take: Cartesian, Geodetic or Grid. Then define the spacing that your CSCS model file should have. This will depend on the required accuracy and on how homogeneous your distortions are. Then convert a regular grid of points once with the corresponding transformation and once without (only apply the projection). The distortion value is simply the difference then. Write the values into a free ASCII file or in an Excel spreadsheet. Organise the grid in rows and columns, and write one point per line, for example as below (Easting and Northing shifts):

```
0.110;0.111      (Grid shifts of 1st point)
0.220;0.221      (Grid shifts of 2nd point)
0.330;0.331      ...
0.440;0.441
```

The SKI-Pro installation contains a tool to convert free ASCII files containing the distortion values into the binary CSC file structure, which SKI-Pro and the System 500 Sensor firmware will understand.



Remember...

- Country Specific Coordinate System Models are a method to convert between WGS84 and Local Grid without having to calculate transformation parameters.
- CSCS Models take the datum and the distortion of the local system into account.
- Different types of CSCS models (Cartesian, Geodetic or Grid) are supported within System 500.
- CSCS Models can be used in SKI-Pro and on the Sensor.
- You can even create your own CSCS model.