Calculating Declination (for Beginners)
(How to use a GPS to authenticate alignments)

This explanation is a fuller account of the method outlined in *Sky and Landscape*: *A Field Guide to Archaeoastronomy* by Irene Earis.

Why More than a Compass is needed

Because of the varying height of the horizon as one stands at a stone circle or megalith and looks around, a magnetic compass is insufficient to show precisely where the sun or moon would rise. For example, if you know that the sun at the summer solstice would rise at your latitude in the north east a compass can indicate the area of the horizon in the north east which you can focus on. But, because the sun rises at sea level and will not be seen until it has moved high enough up the sky to clear the hills on the horizon, more information is necessary to indicate the exact point when it will first appear. This point is usually marked by a cairn on the horizon or a natural notch or slope, but you cannot assume that one of these features, in roughly the right direction, marks the exact position. The peak on the horizon may not have been used as part of an alignment at all or it could, for example, be a lunar alignment rather than a solar one. Some proofs are needed first.

Try to Visit the Site at the right Time

Ideally you would wait for the correct day – e.g one of the solstices, an equinox, a lunar standstill – and visit the site to see the sun or moon rise or set with your own eyes and take photographs to prove it! Remember, though, that the sun will now be about half a degree (its own width) further south from its position around 2500 BCE. However, in practice, bad weather can often prevent one from seeing a set or rise and it may be impossible in busy lives to get to a site at the right time on the right day. You will also probably be impatient to find out if your guess is correct. Certainly 9 or 18 years may be too long to wait to see a lunar standstill! Therefore a theoretical method is also needed.

Declination

A method useful for beginners is based on the concept of *declination*, which is a way of mapping the sky to mirror the latitude lines used for mapping the earth. The imaginary lines projected across the sky are used to describe the lines of travel of the sun, moon or star each day. Because of the tilt of the earth, as we orbit the sun during the course of a year, the sun seems to move south in the winter and north in the summer (in the northern hemisphere) from its position directly over the equator at the equinoxes. This means that there are certain key declination lines along which the sun seems to move during the course of the day, starting with 0° at the spring and autumn equinoxes. The important declinations to look out for are:

-29°	Major Lunar Standstill South
-23°	Winter Solstice
-19°	Minor Lunar Standstill South
-16°	Nov. and Feb. Quarter Days (Samhain and Imbolc)
0°	Equinoxes
+16°	May and Aug. Quarter Days (Beltane and Lughnasadh)
+19°	Minor Lunar Standstill North
+23°	Summer Solstice
+29°	Major Lunar Standstill North

Unlike azimuths, degrees of declination do not vary according to latitude. They change only very slowly with the tilt of the earth. Also remember that, since a degree of declination is a line across the sky, the rise and set each day of the sun or moon will have the same declination.

How to Use a GPS in combination with a Declination Calculator

If an alignment points to a particular place on the horizon, a formula (given below) can be used or a declination calculator on a computer, to find the declination of this point in the sky where it meets the earth. All you need for this are the co-ordinates (as latitude and longitude or grid references) and height above sea level (elevation) of both the backsight (where you are standing) and the foresight (on the horizon). These details are fed into a computer programme, the declination of the horizon point is given and you then have to check against the key declinations above to see if you were right in your guess. Remember, however, that solstice positions in prehistory were further north than they are at present, so you may have to add up to another whole degree for sites dating back to 4000 BCE (i.e. don't worry if the calculator tells you that the declination of the horizon point is greater than 23.5°, the present solstice angle). Check with the historical angles of tilt on Page 38 of *Sky and Landscape*. Equinox positions have remained the same.

A GPS receiver will instantly give you the co-ordinates/grid references and elevation of any spot you want. So in practice you can turn on the GPS at a standing stone or other monument, wait for it to settle to its most accurate reading and make a note of the details. Then walk or drive to any horizon point you think might mark the alignment and get the details from your GPS in the same way. Take the details home, feed them into your computer programme and see if you were right. If the horizon point is too far away to reach, you can use an Ordnance Survey map to ascertain the co-ordinates (grid references) and elevation, but be aware that this may not be as accurate as using a GPS. If the declination given does not match the key ones you are looking out for, you will have to look again at the horizon to see if you were looking at the wrong point – perhaps even in the opposite direction.

In practice, while out walking in an area you have decided to focus on for your research, it is a good idea to make notes of GPS readings at any distinctive stones, natural peaks and so on as you come across them, so you can use them later if necessary when you get home.

Theodolites

If you learn to use a theodolite, you can gain all the information you need from one spot without having to travel to horizon points, but beginners to the subject may prefer to start by using a GPS, which is cheaper to buy and easy to read even for the non-technical person. Theodolites are also heavy to carry across the kind of rough country where cairns and standing stones are often found, though some new ones produced in the Far East are lighter than the traditional British ones.

Get Dec

The declination calculator most readily available at present is the one provided by Leicester University at http://www.le.ac.uk/archaeology/rug/aa/progs/getdec.html

It is called GetDec and is freely offered for anyone interested to download onto their personal computer. (N.B. If you look on the web for a different declination calculator, be aware that this is the name also given to the many programmes that estimate the magnetic variation of compass bearings – i.e. how far west or east True North is from the magnetic north given by the compass).

Maybe some mathematician with IT skills would like to design another programme even simpler to use than GetDec? Get in touch with the Sky and Landscape website if you do!

Below is some advice for people using GetDec for the first time.

Using GetDec

When you download the GetDec programme, instructions are given about how to use it. There is also a "Help" facility if questions arise during the process.

Be prepared to convert elevation figures (i.e the height above sea level) from feet to metres if you are using old maps, but if you set your GPS receiver for metres, you can save yourself the trouble of this process.

The programme suggests you enter "TM grid eastings and northings."
If you are not used to these terms, remember that northings are the grid numbers along the left and right sides of a map (marking latitude) and eastings are the grid references along the top and bottom of a map (marking longitude).

TM is the acronym for Tranverse Mercator and you can also download a converter to change your sets of co-ordinates into TM form. For example, try
http://www.dmap.co.uk/index.htm
For this calculator you enter the co-ordinates (latitude and longitude) of your site in degrees, minutes and seconds and it will instantly convert them to eastings and northings expressed in TM grid references. They are then in the form required by GetDec.

The programme will then tell you not only the sun's "apparent declination" but also the moon's "geocentric lunar declination" as well as the distance between the backsight and foresight, the altitude of the horizon (the angle between the backsight and foresight) and the azimuth (compass bearing) between the two.
Some of this information may seem unnecessary but I suggest you make a note of it all, perhaps keeping a simple filing system in case you want it later. Often a cairn or stone is aligned to more than one point and therefore marks more than one calendar date and you can discover this from home with the Declination Calculator as long as you have recorded the essential information at each site.
Be prepared for having misjudged the potential alignment between your site and the horizon. Sometimes you may be looking for a solar declination, for example, but find that your alignment is to a lunar declination instead.
Take care also when you are back at home not to presume that, for example, two cairns are in alignment because they appear to be from a map. Check at the site itself that the two really are intervisible.

Formula

If you are comfortable with trigonometry and using a calculator another way to find declination is by using the following formula:

$$\sin d = (\sin l \times \sin h) + (\cos l \times \cos h \times \cos az)$$

Where d = declination, l = latitude, h = horizon height and az = azimuth.