

# MAGELLAN

## Manual



**Helios**

ASTRONOMISCHE UHREN

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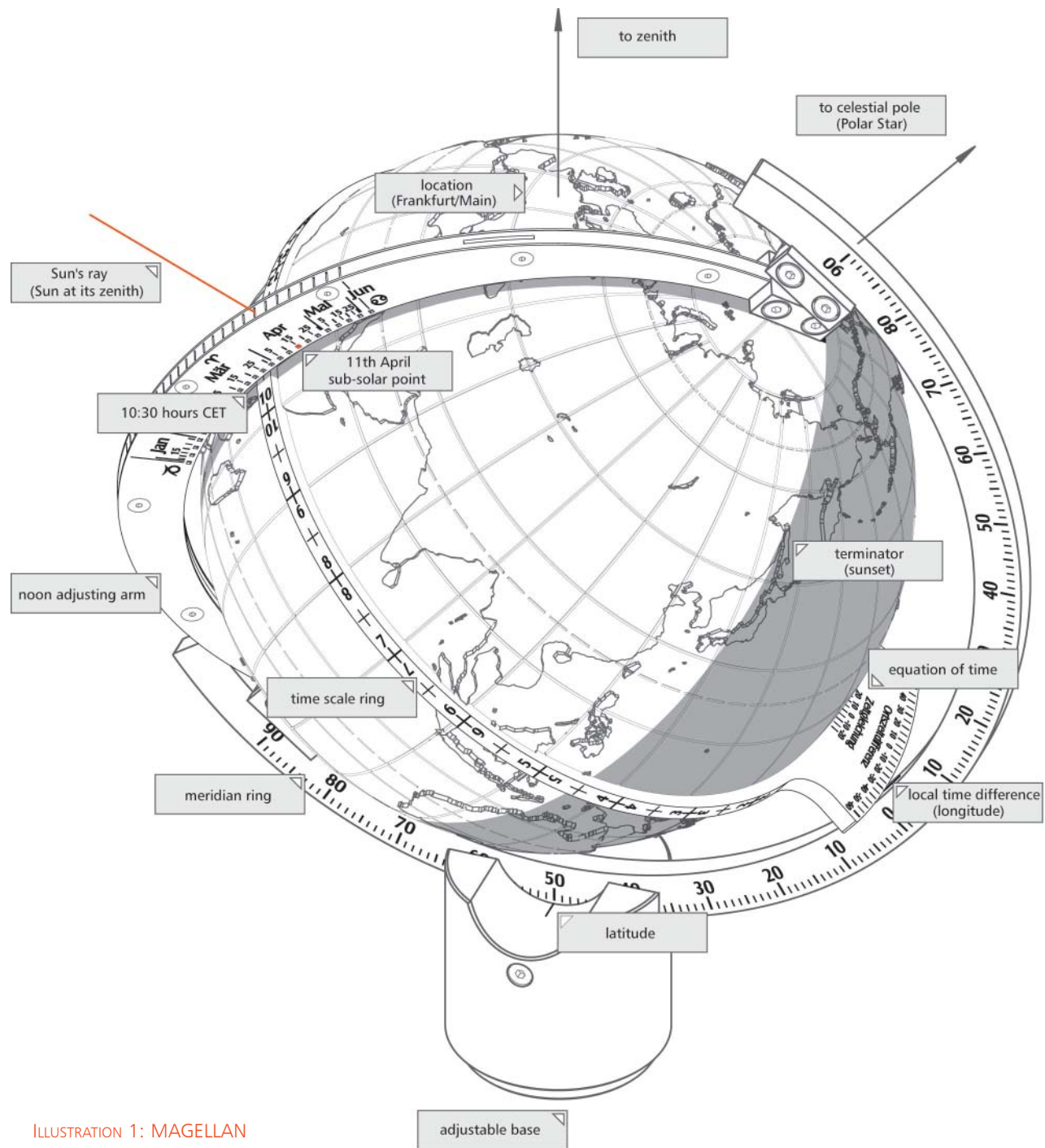


ILLUSTRATION 1: MAGELLAN

# MAGELLAN – Discover Time

Our daily life is determined by the transition from day to night. As a result of the earth's rotation, the sun moves tirelessly from east to west, the location at which the sun reaches its meridian altitude, i.e. its highest point at noon, changes continuously. The MAGELLAN sundial displays the sun's path around the globe in a totally original way.

With the MAGELLAN sundial you can follow the sun's migration across the earth using the noon adjusting arm, which you swivel in the sun until the shadows to the right and the left of the arm disappear. The noon adjusting arm is then positioned directly above the latitude at which the sun is culminating at this moment in time. This means that the sun is currently reaching its local culmination at all locations along this line of latitude, it is now noon. At one location along this line of latitude, the sun's rays meet the earth vertically, here the sun is at its zenith. Its so-called sub-solar (below the sun) point is displayed on the noon arm. The sunlight penetrates the narrow slits in the noon adjustment arm, is reflected to the side and illuminates small light segments, which are at their brightest when they point directly towards the sun. You can ascertain the sub-solar point and read off the date at the most brightly-lit light segment. By observing the sundial this way, you can follow the annual migration of the sun between the tropic of Capricorn and the tropic of Cancer. The beginning of each season is marked by its zodiac signs. The scale of the ascending sun (winter and spring) is on the eastern side of the noon adjusting arm, that of the descending sun (summer and autumn) can be found on the western side.

The MAGELLAN can be used at any location on earth. It can be set up for the geographic coordinates of the location very easily. The time scale ring is adjustable around the equator. This enables you to set Central European Time or any other world zone time. But local apparent time (LAT), representing original sundial time, can also be read off the MAGELLAN.

## Local apparent time – nature's time

Perhaps you have already asked yourself why the sundial which you have just discovered on a church tower does not display the same time as that on your wristwatch? The answer is, the sun displays a different time, i.e. local apparent time. This is nature's time, determined by the sun's path and valid for the place at which the church is located. When the sun has reached its highest point and is exactly in the south, the sundial displays 12:00 hours, it is noon. If we follow this event over several days, we will notice that this happens at totally different times. The time from noon to noon is evidently not always 24 hours, the solar day is sometimes shorter, sometimes longer. The differences cumulate and result in the fact that, during the year, the sundial may be 17 minutes fast and 15 minutes slow compared to the average. There are two explanations for this phenomenon.

Firstly, the earth moves on an elliptical path around the sun and is faster when near the sun than when at a distance. Secondly, the apparent sun moves along the ecliptic path which is at an angle of  $23,4^\circ$  to the celestial equator. Only that part of the sun's path in the direction of the "celestial equator" is relevant for time measurement. This part is also constantly changing throughout the year.

As we can see from this, local apparent time (LAT) is irregular time and is therefore inappropriate for time measurement with mechanical clocks. For this reason, local mean time (LMT) was introduced in the 18th century for large towns. This assumes a fictitious sun which moves towards the celestial equator evenly and includes all location within the same longitude. The difference between mean and apparent time is called the equation of time. Illustration 2 on page 6 shows how the equation of time changes during the year. The MAGELLAN has a scale at 00:00 hours, with which you can set the equation of time so that you can read off the locally valid zone time, e.g. Central European Time.

### Time zones

The invention of the railway during the industrial revolution in the 19th century made it possible to travel long distance. The resulting need for a national rail timetable led to a further standardisation in time: the introduction of Standard Time, valid for specific time zones, by international agreement in 1884. The time zones are one hour apart, exactly the amount of time which the sun takes to move 15 degrees in longitude across the earth. On the MAGELLAN, the zero meridian through Greenwich in London, which is the basis of Universal Time (UT), and the meridians to the east and west at a distance of 15° are visible as representative time zones.

The Standard Time valid for most countries in Europe is Central European Time (CET). This is defined as the local mean time at longitude 15° E and is one hour ahead of Universal Time. To read off CET, 12:00 hours is set on the time zone meridian and the equation of time on the scale is set to 00:00 hours. Central European Summer Time (CEST) is one hour ahead of CET, so 13:00 hours is then set at 15° E.

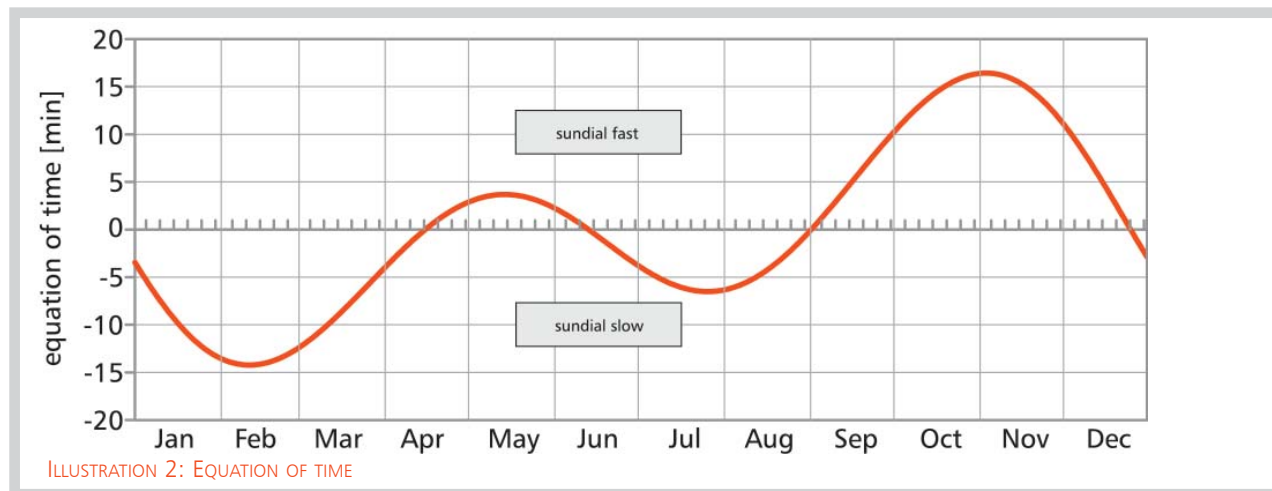
In illustration 3, the MAGELLAN is installed at three different locations in the world. It is 13th of June, 10:00 hours Universal Time (UT), the equation of time is 0 minutes and true noon takes place at longitude 30° E. At Frankfurt/Main, the sundial shows 11:00 hours CET

or 12:00 hours CEST. In Cape Town the Standard Time is South Africa Standard Time (SAST), which is longitude 30° E and is two hours ahead of Universal Time (UT). There it is 12:00 hours SAST. The Standard Time in Singapore is Singapore Time (SGT), this is measured at longitude 120° E and is eight hours ahead of Universal Time. Here you can read off a time of 18:00 hours SGT.

### Terminator – the border between night and day

Once you have installed and adjusted the MAGELLAN, the globe will have the same alignment as the planet Earth. The polar axis points toward the celestial pole, which is very close to the Polar Star in the night sky. The sun then illuminates the globe as it does the real earth, so that the day and night hemispheres are visible on the MAGELLAN. The terminator, the border between night and day, shows us where the sun is rising or setting at this moment in time. You can also observe polar night and polar day at the North and South Poles on the MAGELLAN.

These natural phenomena are displayed independent of the MAGELLAN's location. When installed according to longitude and latitude, the MAGELLAN always assumes the same alignment as the planet Earth, as can be seen in illustration 3. The three sundials at different locations





in the world each displays the relevant Standard Time, however, they are always lit by the sun in the same way. Maintaining the “real” alignment of the globe means that at each location the globe is aligned in a different way to the local horizontal level. For example, an observer in Cape Town sees the MAGELLAN in an unusual light. It is upside down, Cape Town is right at the top, the

South Pole is towards the sky, while the North Pole is toward the ground. In Singapore, the MAGELLAN’s polar axis will be almost horizontal and the equator level will be vertical. In Frankfurt, the polar axis will be at a 50° angle to the horizon, which is similar to the usual view. Globes are usually tilted to 66,6°, which is equivalent to the tilt of the earth’s axis to its path around the sun.

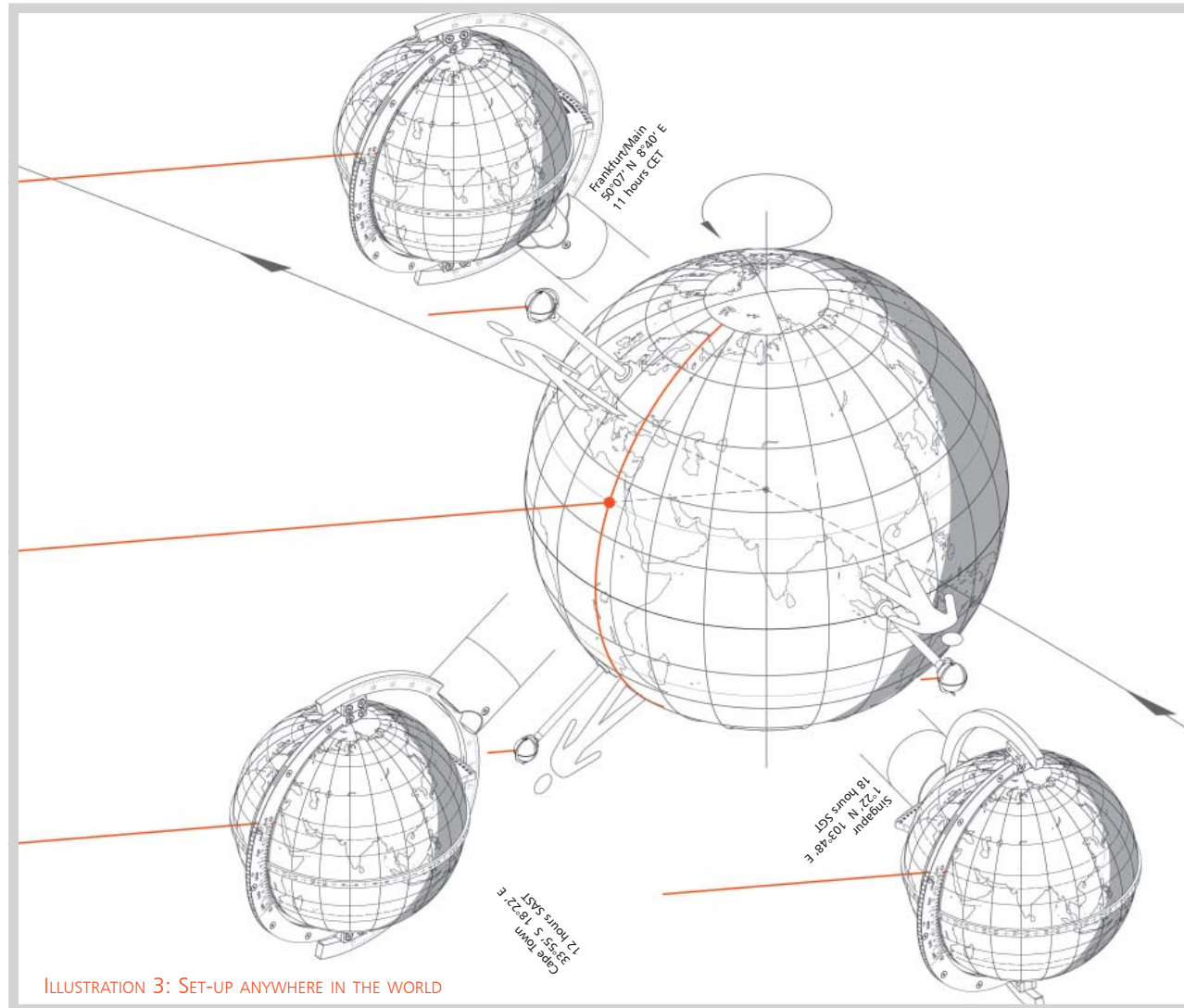


ILLUSTRATION 3: SET-UP ANYWHERE IN THE WORLD

# Installation and Adjustment

The MAGELLAN is a precision instrument, which can display the exact time and noon position of the sun, provided it is installed and adjusted according to the following instructions. Everything you need for installation is included with the delivery package. To make the holes for the rawl-plugs, you will need to use a hammer drill with appropriate drilling bits.

For final adjustment, please choose a day when the sun is shining, since you need the sun to set the sundial exactly.

If you have questions on the installation and use of the sundial, you can reach us at the following address:

HELIOS (EK)  
Begasweg 3  
D - 65195 Wiesbaden  
Tel +49 611- 185 11 06  
Fax +49 611-59 83 29  
Email: [info@heliosuhren.de](mailto:info@heliosuhren.de)

## Preparation

In order for the MAGELLAN to display the correct time, it has to be adjusted for the geographic co-ordinates of the installed location. The geographic latitude and longitude must first be determined. There are various options for doing this :

- > The geographic co-ordinates are noted around the edge of topological maps or ordnance survey map, so that you can read off the co-ordinates for the installed location.
- > If you have a navigation system (GPS) in your car, you can use this to precisely define the co-ordinates.
- > You can send us a query via email or fax with the heading „Co-ordinates“ and your full address. We will then define the co-ordinates from your address details and send these to you by email with an excerpt from the city map. From the geographic

position, we can also determine the time difference to the standard meridian, which you will need to set the local meridian.

Once you know the geographic co-ordinates, you can start to install and adjust the sundial.

## Installing the base

Select a position in the sun for your MAGELLAN. A location at which the sun shines for most of the day and which is not overshadowed by trees or houses. The first step is to securely stabilise the base plate in the ground at the selected location. Appropriate locations might be the projection of a wall, railings or a stone pedestal.

HELIOS (EK) also offers matching stands made of stainless steel or granite as extras, which you can secure on a balcony or in the earth using the stabilizing anchor which we also offer. We will be glad to advise you on your choice of location.

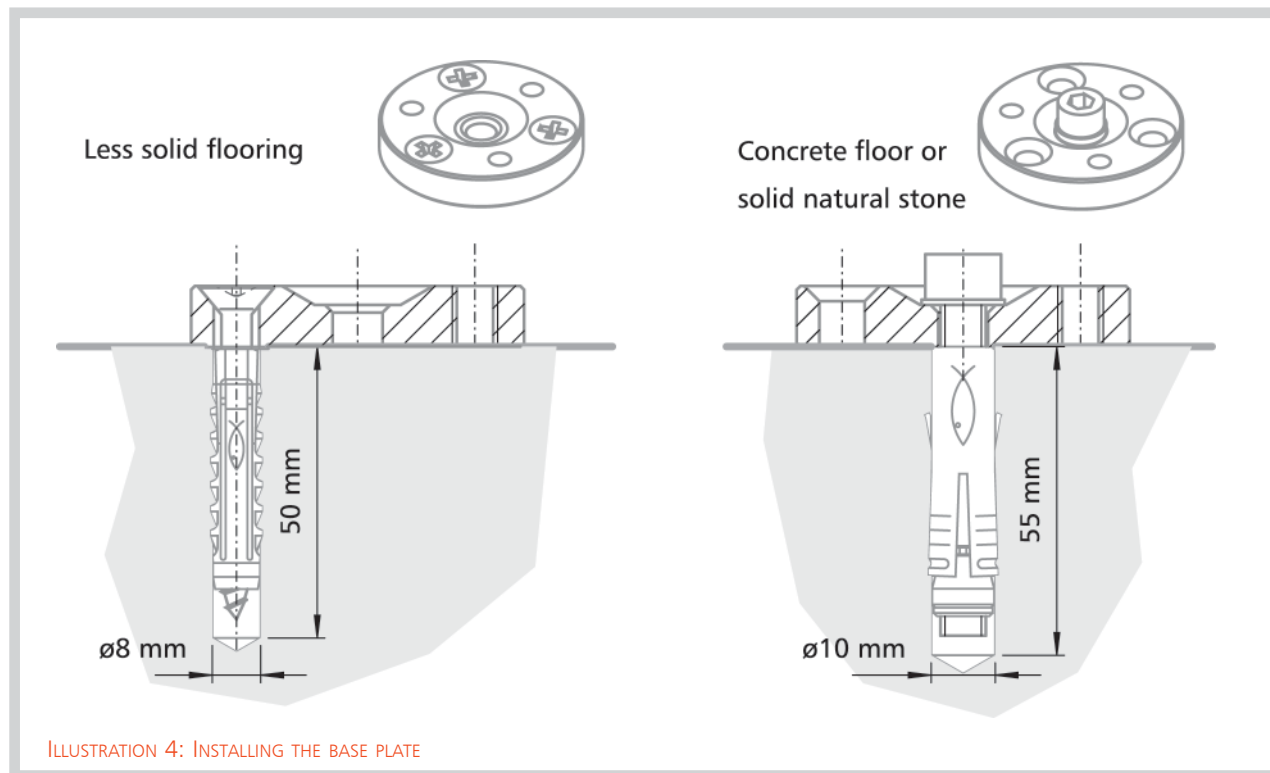
The appropriate securing device is available for whatever flooring type prevails (see illustration 4):

### Concrete floor or solid natural stone

The heavy-duty rawlplug is appropriate for installation on concrete or solid natural stone flooring. First, place the base plate at the selected location. Turn and push the base plate until you have found a position in which it will not tilt. Mark the drilling point in the central drill hole. Using a 10 mm concrete drill, drill a hole at least 60 mm deep. Hammer the rawl-plug into the drill hole and secure the base plate with a washer and the machine screw. Turn the screw in very tightly.

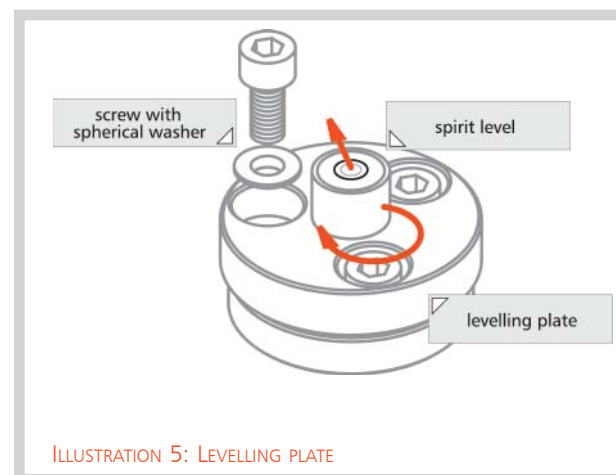
### Less solid flooring

Three universal rawlplugs are provided for less solid flooring (e.g. tiles). First position the base plate at the desired location and turn and push it until you have found a position in which it does not tilt. Mark the drilling points in the outer three drill holes. Using an 8 mm

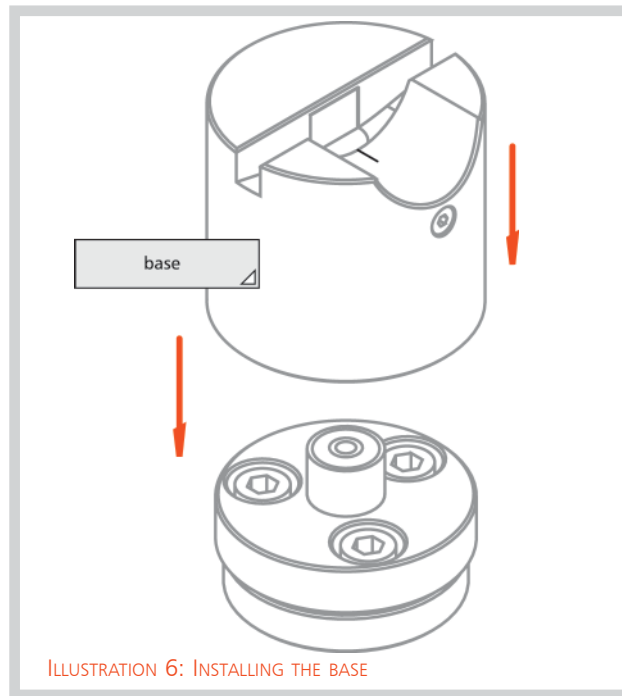


concrete drill, drill a hole at least 50 mm deep at the three points. Hammer the rawl-plugs into the drill holes and secure the base plate with three Phillips screws.

Place the levelling plate on the base plate and loosely screw in the three screws with the spherical washers. Position the levelling plate so that the bubble in the spirit level is within the black circle. Now press the levelling plate firmly into its socket with one hand, while tightening the screws with the other hand, ensuring that the bubble remains within the black ring. As can be seen in illustration 5, the bubble moves away from a screw as it is being tightened. If the screws are tightened cyclically, the bubble stays in the centre. Now the base is placed on the levelling plate (see illustration 6).







### Setting up the sundial for its installed location

The setting-up takes place in three steps. As an example, we will select Frankfurt/Main as the sundial's location. The geographic co-ordinates for Frankfurt are: latitude 50°06' N, longitude 8°42' E.

#### Positioning the polar axis

The globe is hung on the meridian ring and is now placed in the stand. The scale allows you to set the geographic latitude. For locations on the southern hemisphere, you should use the scale from the equator to the North Pole, for the northern hemisphere the scale from the equator to the South Pole. In the example, the scale is set at 50°06' = latitude 50,1° N (see illustration 1). The polar axis now has the same angle to the horizontal level as the earth's axis. Now gently tighten the fastening screw on the base (see illustration 6), so that the globe

no longer wobbles, but the base can still be turned, so that it can later be turned towards the south.

#### Setting the local meridian

The local meridian is an imaginary circle which runs from the North Pole through the installed location (for example Frankfurt) to the South Pole and back. The meridian which runs through Greenwich is the zero meridian. The angle of the local meridian to the zero meridian is equivalent to the geographic longitude. For this step, the globe is turned so that the local meridian is on the same level as the meridian ring (see illustration 7). To help with this setting, a scale is fixed to the time scale ring, on which the difference between local time and the standard meridian can be set. The time zone valid for Frankfurt is Central European Time (CET). This is the local mean time (LMT) at longitude 15° E. The difference in the degree of longitude between the local meridian and the meridian at 15° E results from the following calculation:

$$\begin{aligned} \text{Difference in longitude} &= \\ \text{Longitude of installed location} &- \text{Longitude standard} \\ &\text{meridian} \end{aligned}$$

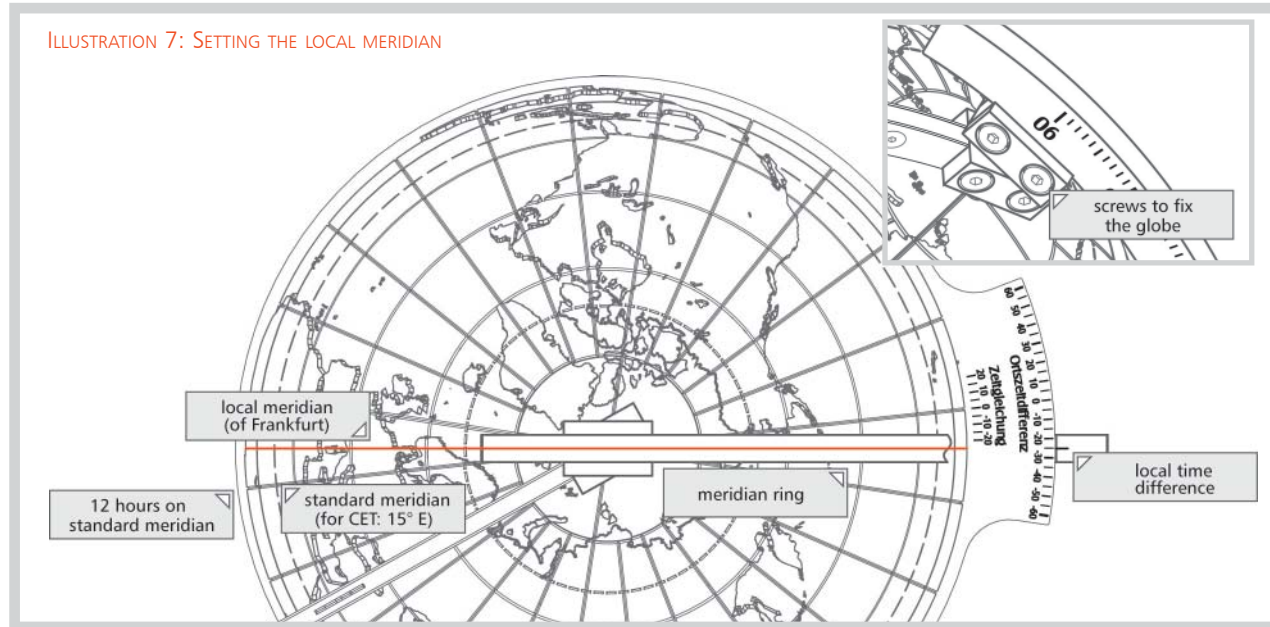
$$\text{Difference in longitude} = 8^{\circ}42' - 15^{\circ} = -6^{\circ}18' = -6,3^{\circ}$$

The longitude is calculated positively in an easterly direction. Frankfurt lies to the west of the standard meridian, so the result is negative. The sun takes an hour to travel 15°, four minutes for one degree. So that the time required for the sun to travel from the standard meridian to the local meridian:

$$\text{Local time difference} = -6,3^{\circ} \times 4 \text{ min} = -25,2 \text{ min}$$

The minus sign indicates that the local time in Frankfurt is later than the local time at longitude 15° E. You should now set 12:00 hours on the time scale ring on the standard meridian, in the example to 15° E. Now loosen each of the four fastening screws on the polar axes (see illustration 7) by a quarter of a turn, and turn the globe until at 00:00 hours the local time difference (-25,2 minutes in the example) on the outer scale matches the marker line on the meridian ring. You should then fix the globe by tightening the four screws on the polar axes.

ILLUSTRATION 7: SETTING THE LOCAL MERIDIAN

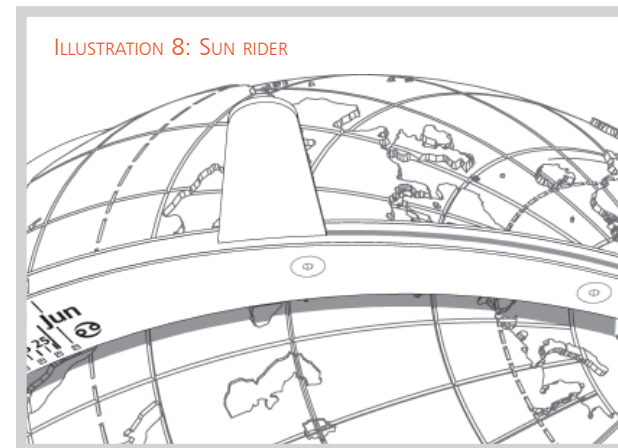


There are countries in the world for which the time at the nearest standard meridian is not valid. For practical or political reasons, a different standard meridian is used. For example, the clocks in Spain display Central European Time, but the greater part of the country is located more than 15° west of the CET standard meridian. The local time difference is therefore greater than one hour, so that it cannot be set on the MAGELLAN. In this case, you can set 12:00 hours on the nearest standard meridian and calculate the local time difference to this meridian. In the case of Spain, this will be the zero meridian. To read off the time, you then use the standard meridian valid for that country.

#### Setting up the MAGELLAN in a north-south alignment

The final adjustments are made in setting up the MAGELLAN in a north-south alignment. For this step you do not need a compass, the MAGELLAN can be set using an accurate clock or watch. It is then automatically set up in a north-south alignment. For this step, you first insert the enclosed sun rider in the slit provided in the noon adjusting arm (illustration 8). If the currently valid time

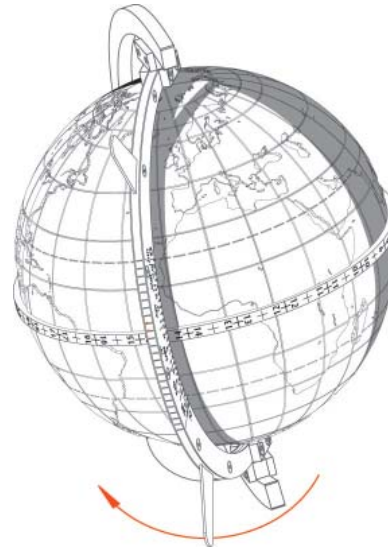
is summer time, first set 13:00 hours on the standard meridian, if not, leave the 12:00 hours set during the previous step (see illustration 9a). Now set the equation of time. To do this, choose the relevant value from table 1 in the attachment. Here you will find the average values for equation of time. For example, let us assume it is the 11<sup>th</sup> of March, then the equation of time is



[a] Setting 12:00 hours CET or 13:00 hours CEST on the time zone meridian



[b] Setting equation of time and the noon adjusting arm to a "full hour" time. When the time is reached, turn base, until shadow under noon adjusting arm is minimal.



[c] Correctly set sundial on 11th March at 14:30 hours: shadow under noon adjusting arm, rider shadow centred and date display correct.

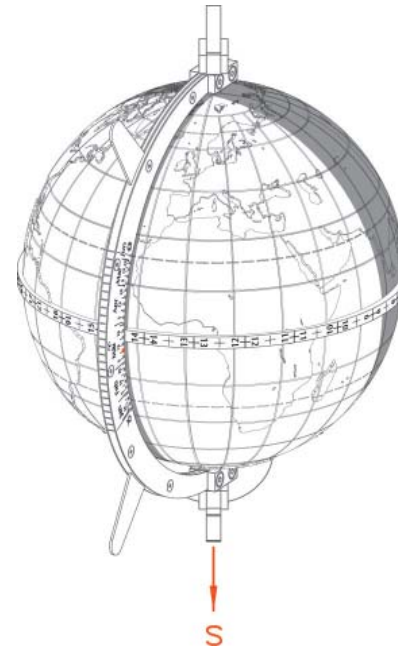


ILLUSTRATION 9: SOUTHERN ALIGNMENT

-10 minutes. You should set this value on the meridian at 00:00 hours (see illustration 10). Now find a time in the near future, which is displayed on the time scale ring, for example 14:30 hours. As soon as this time (14:30 hours) has been reached, turn the MAGELLAN's base (not the arm!) until the shadows to the left and right of the noon adjusting arm disappear and the shadow is positioned directly above the line at the setting for 14:30 hours. The shadow of the sun rider which has been inserted provides additional help when setting the time and should fall directly in the middle of the adjusting arm (illustration 9c). Finally, tighten the screw to secure the adjustment and prevent misalignment.

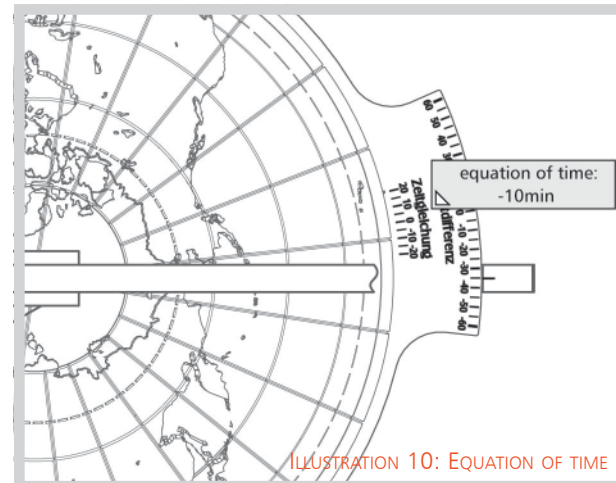


ILLUSTRATION 10: EQUATION OF TIME

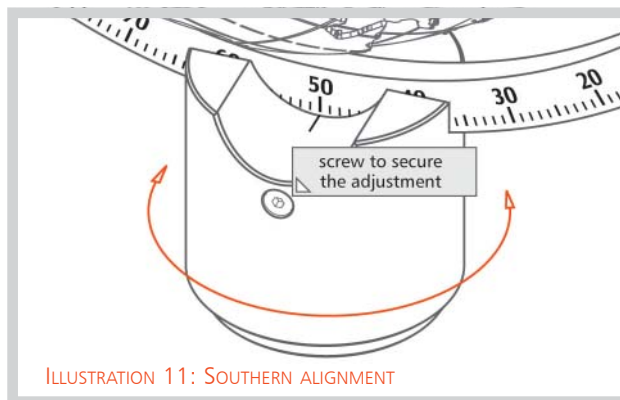


ILLUSTRATION 11: SOUTHERN ALIGNMENT

The adjustment of the sundial is now complete, it is now set up to the south and the globe has the same alignment as the real earth, it is illuminated in exactly the same way, so that in bright sunlight the day and night hemispheres are visible. The polar axis points toward the celestial pole, near to which the Polar Star is located and the location, in our example Frankfurt/Main, is at the top of the globe and points towards the zenith.

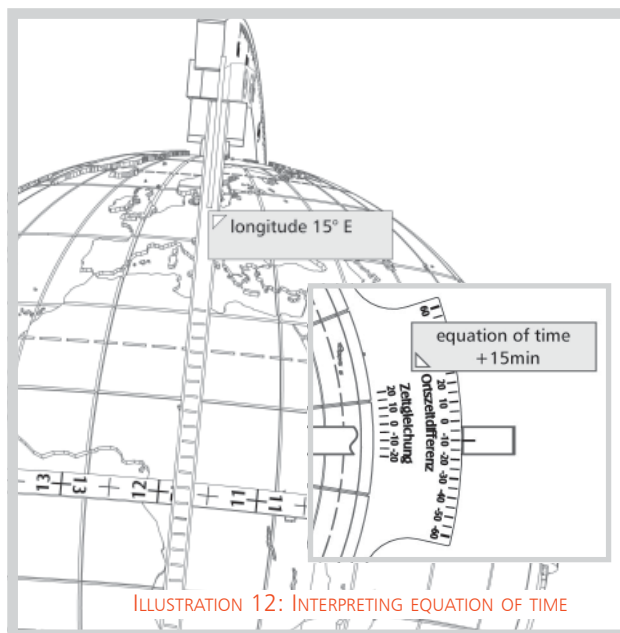


ILLUSTRATION 12: INTERPRETING EQUATION OF TIME

## Use of the MAGELLAN

The MAGELLAN offers you a lot of information associated with the sun's daily movement, all of which can be read off the sundial.

### Standard Time

In setting up the north-south alignment, you have already set the Standard Time, for example Central European Time for Frankfurt. You can now read off the time accurately all day long. However, after a few days, you will notice that the time varies. To avoid this, you should regularly set the equation of time value from table 1 valid for the current date on the time scale ring at 0 hours. The MAGELLAN shows us clearly how to interpret the equation of time, as you can see in illustration 12. On 17th November the equation of time value is +15min. This means that local apparent time (LAT) is 15 minutes ahead of local mean time (LMT). So on this day, the sun will reach longitude 15° O at 11:45 hours local mean time (LMT). Since in this case local mean time (LMT) is the same as Central European Time (CET), it is 12:00 hours local apparent time at 11:45 hours CET.

If the equation of time has a minus sign, local apparent time is behind. For example, on 11th March true noon at longitude 15° O takes place at 12:10 hours CET. Local apparent time (LAT) and local mean time (LMT) are only concurrent for four days per year. On April 15th, June 13th, September 1st and December 25th, the equation of time is zero. To view equation of time throughout the year see the illustration on page 6.

### Summer time

Summer time, which has been introduced in many countries during the summer months, can be set on the MAGELLAN by moving the time scale ring by one hour in an easterly direction. This means that 13:00 hours will be located at the standard meridian instead of 12:00 noon. Equation of time is again set at 00:00 hours.

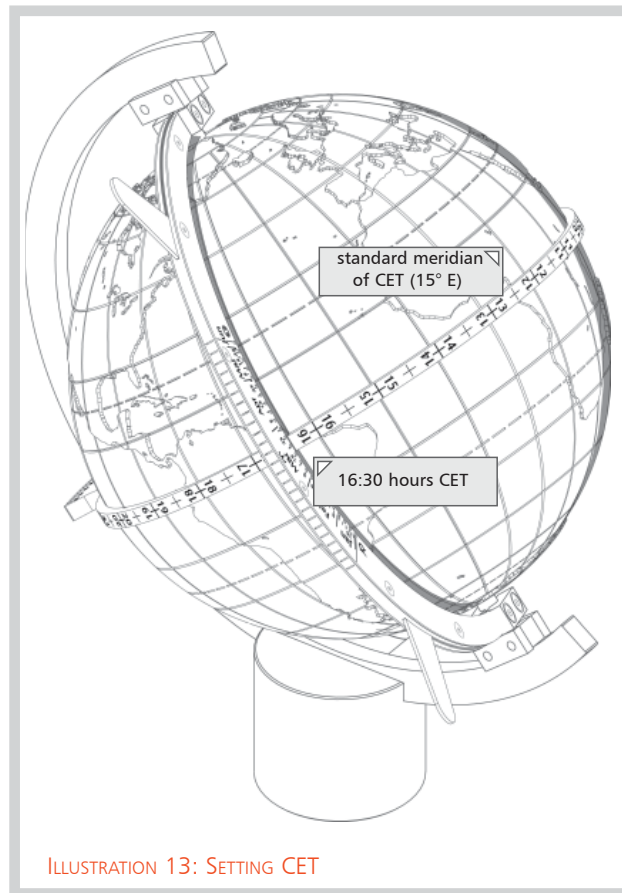


ILLUSTRATION 13: SETTING CET

### *All the time in the world*

You can also set any other Standard Time on the MAGELLAN. For example, on 15<sup>th</sup> April (equation of time = 0 min), you can read off 16:30 hours CET in Frankfurt (illustration 13). If you are interested in knowing what time it is in New York, set the sundial to 12:00 hours longitude 75° W. Now read off the Eastern Standard Time valid for New York, in the example this is 10:30 hours EST. EST is 5 hours behind Universal Time Coordinated (UTC), so it would be 15:30 hours UTC in London, 16:30 hours CET in Frankfurt.

For the summer months, Eastern Daylight Time (EDT) is valid for New York. To read this off, 13:00 hours is set at

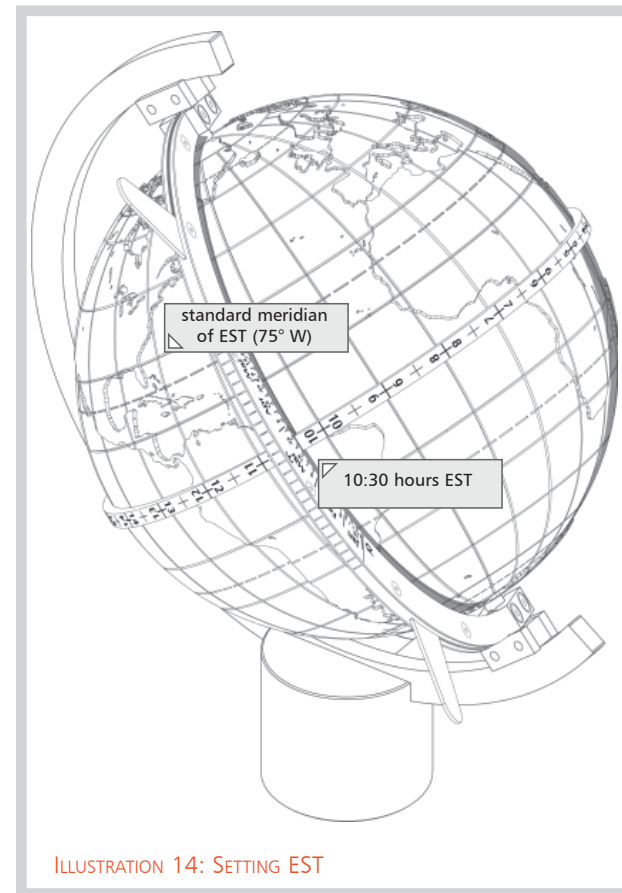


ILLUSTRATION 14: SETTING EST

75° W. The equation of time is always set on the meridian at 0 hours.

Illustration 15 shows important world time zones and their time difference compared to UTC.

### *Local Apparent Time (LAT)*

Of course, you can also set Local Apparent Time (LAT) for the location on the MAGELLAN. Local Apparent Time (LAT), also known as solar time, is directly determined by the sun's movement. It is 12:00 hours Local Apparent Time (LAT) when the sun passes the local meridian and reaches its meridian altitude. Turn the time scale ring until the 00:00 hours mark corresponds exactly with



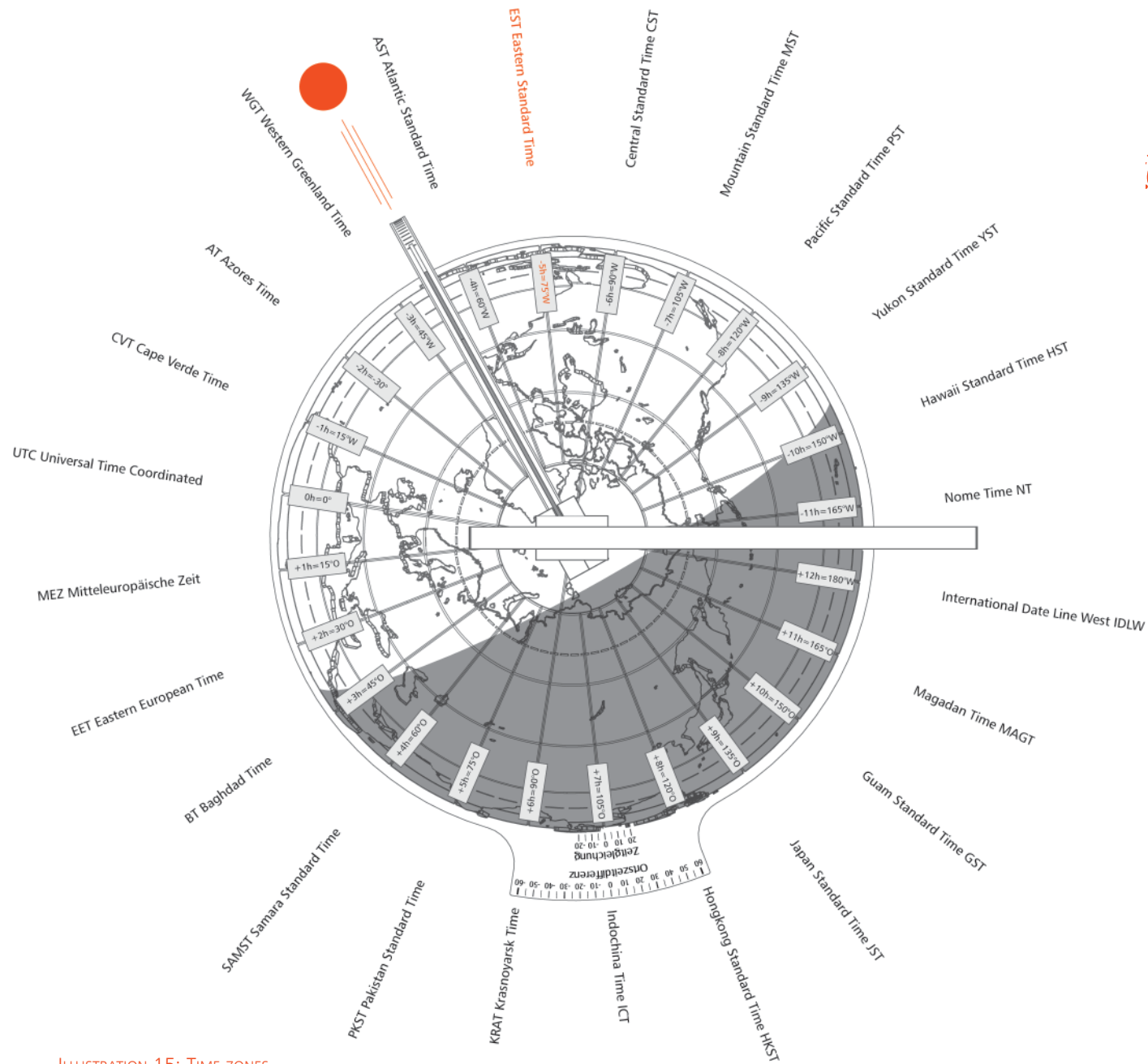


ILLUSTRATION 15: TIME ZONES

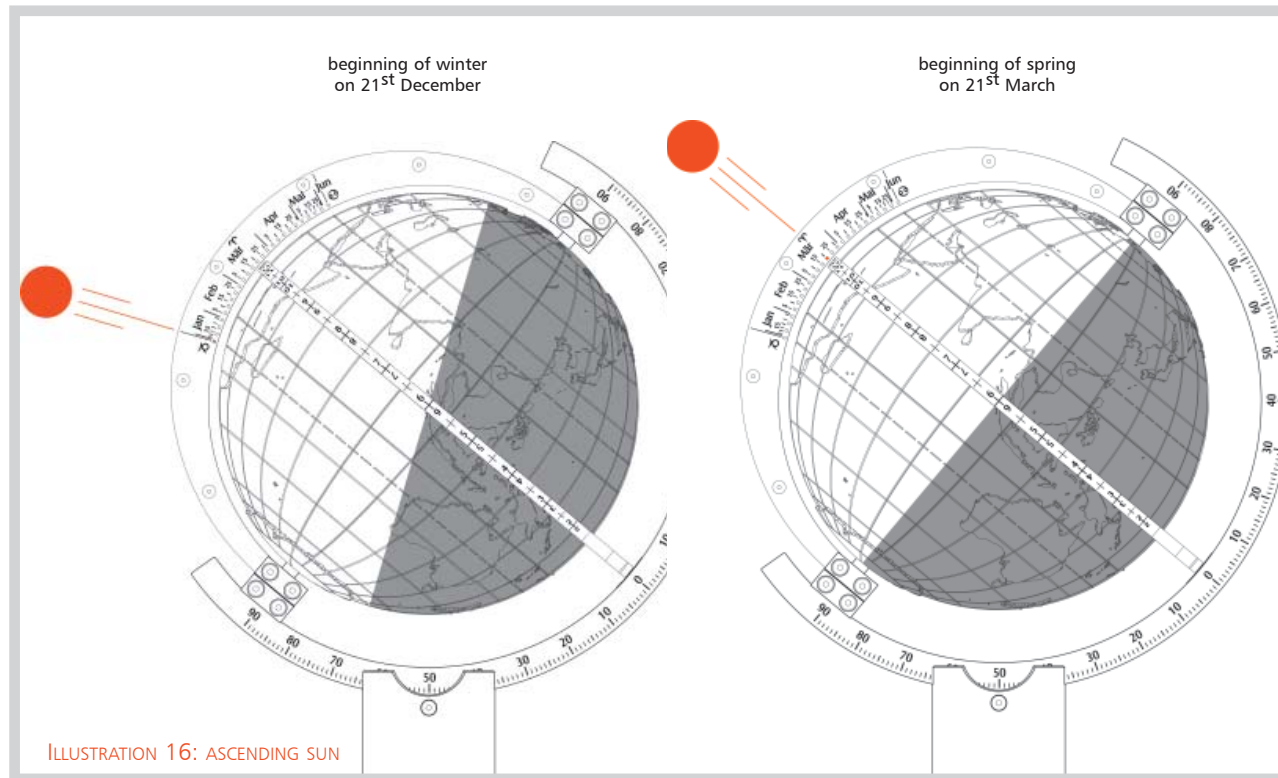


ILLUSTRATION 16: ASCENDING SUN

the mark on the meridian ring, and it is 12:00 hours at the local meridian. In illustrations 12 to 14 the MAGELLAN displays 10:00 hours Local Apparent Time (LAT) in Frankfurt for different seasons. In contrast to Local Mean Time (LMT) or Standard Time, Local Apparent Time (LAT) is independent of the date. Equation of time is not relevant.

Illustrations 16 and 17 show the MAGELLAN at 12:00 hours LAT in Frankfurt/Main for different seasons.

### Noon

Just as in Frankfurt, it is true noon at every location in the world at sometime during the day. This event occurs at the longitude at which the noon adjusting arm is positioned, which is pointing directly at the sun. At all locations on this longitude, the sun is culminating, i.e. it

is just reaching its highest point. In the northern hemisphere it is located exactly in the south, in the southern hemisphere in the north. In the tropical zone between the tropics, it takes up both positions depending on the season, and on one day of the year is in its zenith at true noon. This so-called sub-solar point is positioned on the globe below the light segment showing the date.

### Day and night - winter, spring, summer and autumn

Our Earth rotates around its axis daily and orbits the sun once a year. The MAGELLAN is securely installed at the chosen location. It moves in exactly the same way as the earth and lights up in exactly the same way, so that the day and night hemispheres are recognizable. The terminator, the border between day and night moves daily from east to west. The sun sets on the eastern border

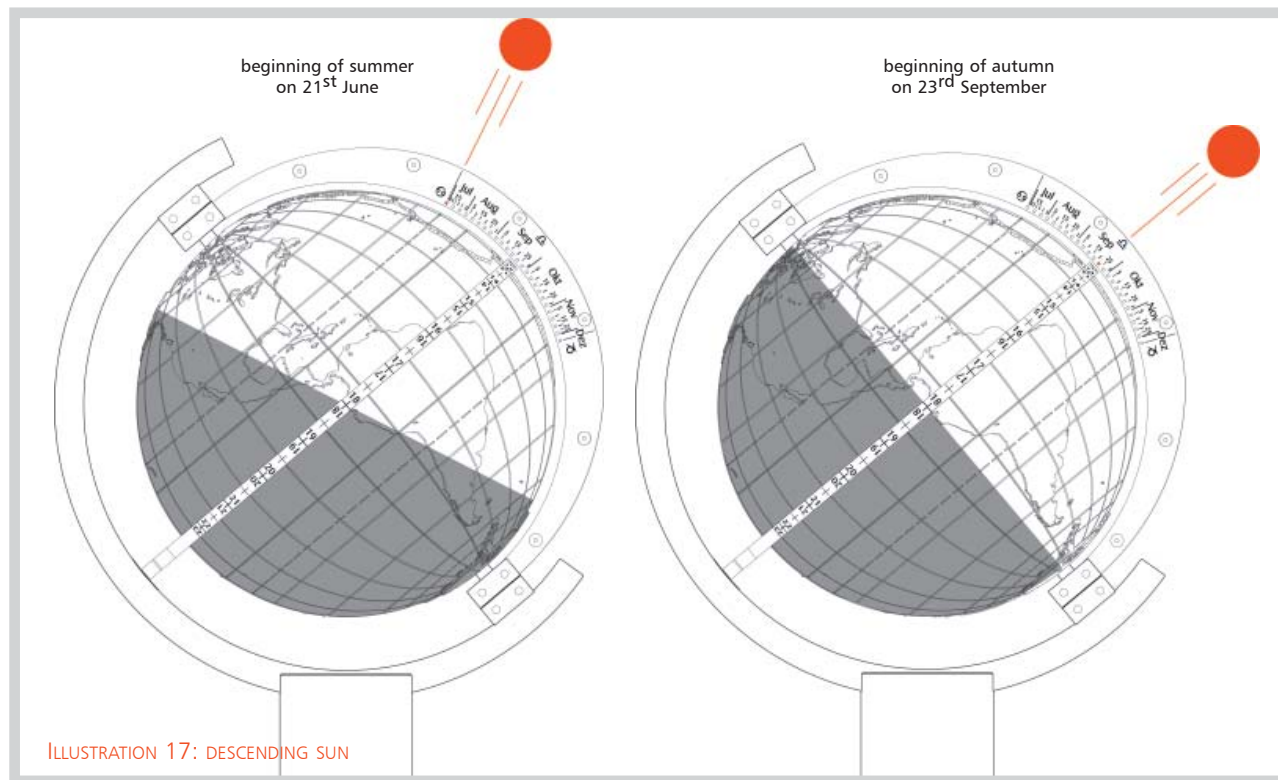


ILLUSTRATION 17: DESCENDING SUN

and rises on the western border.

The seasonal change in the earth's illumination can be visibly perceived. The Earth's axis is tilted to  $23,4^\circ$  to the vertical at the level of the earth's orbit. During the earth's orbit around the sun, the earth's axis always points towards the Polar Star, its direction to the sun changing constantly (illustration 15). This means that the angle of the sun to the earth's equator changes depending on the season. This angle is called the declination.

On the MAGELLAN's noon adjusting arm, you can follow the sun's apparent migration between the tropics all year round and ascertain the date. The beginning of each of the four seasons is marked by the zodiac signs of the ancient world.

At the winter solstice on December 21st (illustration 16 left), the sun is in the southern tropics (declination =

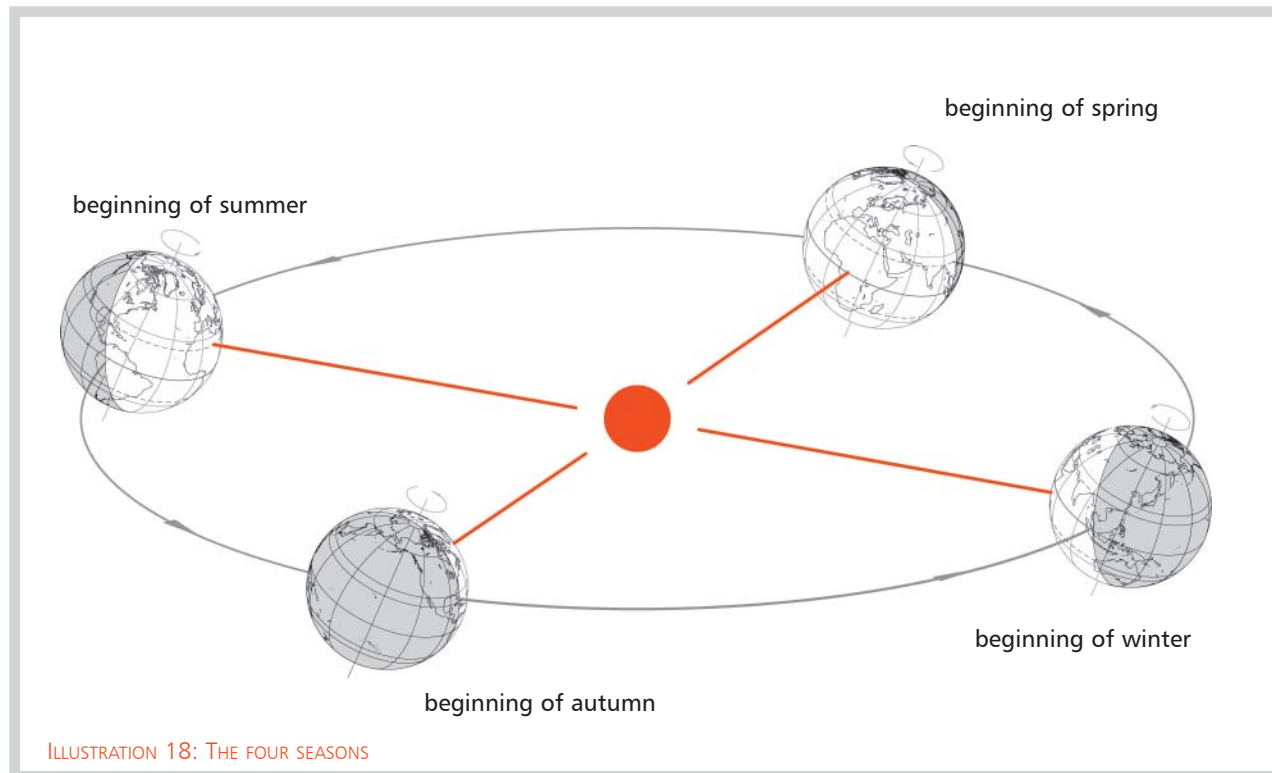
$-23,4^\circ$ ). Seen from the northern half of the earth, it is taking its lowest daily path across the horizon. The complete northern Polar Circle remains in darkness throughout this day. In comparison, the South Pole experiences polar day (no night). From this day onwards the sun moves upwards and follows a higher path each day, until it is exactly above the equator at a declination of  $0^\circ$  for the beginning of spring on March 21st (see illustration 16 right). Day and night are of equal length, the terminator passes precisely through the North and the South Pole. From this day onwards, the sun does not set in the North Pole for six months, during this time the South Pole remains in darkness. On June 21st at the summer solstice (see illustration 17 links), the complete northern Polar Circle is lit up all day, the sun reaches the northern tropics (declination =  $+23,4^\circ$ ), in the northern hemisphere it reaches its highest daily path. From this date onwards it moves downwards and will cross the equator

on 23rd September (see illustration 17 right) in a southerly direction. It is now equinox again and autumn is beginning in the northern hemisphere. On 21st December winter starts and the seasonal cycle recommences from the beginning.

The noon arm should always be movable with only slight resistance and remain at any position, so that the time can easily be read. The adjusting arm's friction can be adjusted using the **back** screw of the two mountings with which the arm is attached to pivot around the polar axis. If the arm moves by itself, you can tighten the screws. If the arm is difficult to move, the screws can be loosened.

## Maintenance

The MAGELLAN sundial does not require any specific maintenance. However, heavy soiling may affect the rotability of the time scale ring around the equator and the penetrability of the light slot for date display. For cleaning and maintenance, you can send the sundial in its original packaging to HELIOS (EK), Begasweg 3, 65195 Wiesbaden.



	Jan	Feb	Mär	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov	Dez
1.	- 3:28	-13:33	-12:24	- 3:57	+ 2:53	+ 2:14	- 3:47	- 6:20	- 0:05	+10:15	+16:24	+11:04
2.	- 3:56	-13:41	-12:12	- 3:39	+ 2:60	+ 2:05	- 3:59	- 6:16	+ 0:15	+10:35	+16:25	+10:41
3.	- 4:24	-13:48	-11:60	- 3:22	+ 3:07	+ 1:55	- 4:10	- 6:12	+ 0:34	+10:54	+16:26	+10:18
4.	- 4:51	-13:54	-11:47	- 3:04	+ 3:12	+ 1:45	- 4:21	- 6:06	+ 0:54	+11:12	+16:26	+ 9:54
5.	- 5:18	-13:59	-11:34	- 2:47	+ 3:18	+ 1:35	- 4:31	- 6:01	+ 1:14	+11:30	+16:24	+ 9:30
6.	- 5:45	-14:04	-11:20	- 2:30	+ 3:23	+ 1:24	- 4:42	- 5:54	+ 1:34	+11:48	+16:23	+ 9:05
7.	- 6:11	-14:07	-11:06	- 2:13	+ 3:27	+ 1:13	- 4:52	- 5:47	+ 1:54	+12:06	+16:20	+ 8:39
8.	- 6:37	-14:10	-10:51	- 1:56	+ 3:31	+ 1:02	- 5:01	- 5:40	+ 2:15	+12:23	+16:16	+ 8:13
9.	- 7:02	-14:12	-10:36	- 1:39	+ 3:34	+ 0:50	- 5:10	- 5:32	+ 2:35	+12:40	+16:12	+ 7:47
10.	- 7:26	-14:13	-10:21	- 1:23	+ 3:36	+ 0:38	- 5:19	- 5:23	+ 2:56	+12:56	+16:06	+ 7:20
11.	- 7:50	-14:14	-10:05	- 1:07	+ 3:38	+ 0:26	- 5:27	- 5:14	+ 3:17	+13:12	+15:60	+ 6:52
12.	- 8:14	-14:14	- 9:50	- 0:51	+ 3:40	+ 0:14	- 5:35	- 5:04	+ 3:38	+13:27	+15:53	+ 6:25
13.	- 8:37	-14:13	- 9:33	- 0:36	+ 3:41	+ 0:01	- 5:42	- 4:54	+ 3:59	+13:42	+15:45	+ 5:57
14.	- 8:59	-14:11	- 9:17	- 0:21	+ 3:41	- 0:11	- 5:49	- 4:43	+ 4:21	+13:56	+15:36	+ 5:28
15.	- 9:20	-14:08	- 9:00	- 0:06	+ 3:41	- 0:24	- 5:56	- 4:31	+ 4:42	+14:09	+15:27	+ 4:59
16.	- 9:41	-14:05	- 8:43	+ 0:08	+ 3:40	- 0:37	- 6:02	- 4:19	+ 5:03	+14:23	+15:16	+ 4:30
17.	-10:02	-14:01	- 8:26	+ 0:22	+ 3:38	- 0:50	- 6:07	- 4:07	+ 5:25	+14:35	+15:05	+ 4:01
18.	-10:21	-13:57	- 8:09	+ 0:36	+ 3:36	- 1:03	- 6:12	- 3:54	+ 5:46	+14:47	+14:53	+ 3:32
19.	-10:40	-13:51	- 7:51	+ 0:49	+ 3:34	- 1:16	- 6:16	- 3:40	+ 6:08	+14:59	+14:40	+ 3:02
20.	-10:58	-13:45	- 7:34	+ 1:02	+ 3:31	- 1:29	- 6:20	- 3:26	+ 6:29	+15:09	+14:26	+ 2:32
21.	-11:15	-13:39	- 7:16	+ 1:15	+ 3:27	- 1:42	- 6:23	- 3:12	+ 6:50	+15:19	+14:12	+ 2:03
22.	-11:32	-13:31	- 6:58	+ 1:27	+ 3:23	- 1:55	- 6:26	- 2:57	+ 7:11	+15:29	+13:56	+ 1:33
23.	-11:47	-13:24	- 6:40	+ 1:38	+ 3:18	- 2:08	- 6:28	- 2:41	+ 7:33	+15:38	+13:40	+ 1:03
24.	-12:02	-13:15	- 6:22	+ 1:49	+ 3:13	- 2:21	- 6:30	- 2:26	+ 7:54	+15:46	+13:23	+ 0:33
25.	-12:17	-13:06	- 6:04	+ 1:60	+ 3:07	- 2:34	- 6:31	- 2:09	+ 8:14	+15:53	+13:06	+ 0:03
26.	-12:30	-12:56	- 5:46	+ 2:10	+ 3:01	- 2:47	- 6:31	- 1:53	+ 8:35	+15:60	+12:47	- 0:26
27.	-12:43	-12:46	- 5:28	+ 2:19	+ 2:54	- 2:59	- 6:31	- 1:36	+ 8:56	+16:06	+12:28	- 0:56
28.	-12:54	-12:35	- 5:09	+ 2:29	+ 2:47	- 3:11	- 6:30	- 1:18	+ 9:16	+16:11	+12:08	- 1:25
29.	-13:05		- 4:51	+ 2:37	+ 2:39	- 3:24	- 6:28	- 1:00	+ 9:36	+16:15	+11:47	- 1:55
30.	-13:16		- 4:33	+ 2:45	+ 2:31	- 3:36	- 6:26	- 0:42	+ 9:56	+16:19	+11:26	- 2:24
31.	-13:25		- 4:15		+ 2:23		- 6:23	- 0:23		+16:22		- 2:53

TABLE 1: EQUATION OF TIME IN MIN:SEC