

From Pehr Wilhelm Wargentin to the moon eclipse



INTRODUCTION



Who was Pehr Wilhelm Wargentin?

Wargentin was born in 1717 in Sunne, Jämtland, Sweden and died in Stockholm, Sweden 1783. He was an astronomer and demographer. In his essay "De satellitibus Jovis" Wargentin determined the movement and orbit of the moons of Jupiter. He also published research within the field of magnetism, Nordic light and climate and weather. He co-operated with Anders Celsius on the development of the centigrade thermometer.

In 1749 he started the Foundation of Swedish Statistics on population – an instrument for the Swedish government to monitor the life of the Swedish inhabitants in detail. This

makes him one of the leading personalities in Statistical Sciences.

Wargentin was the first director of the Stockholm Observatory and between 1749-1783 he held the position of Secretary of the Swedish Royal Academy of Science. The crater Wargentin on the Moon is named after him.





	PART 1		
Торіс	Weather station		
Subjects	Science, Technology, Engineering		
Level	$\star \star \bigstar$		
Aims	Students learn about the sensors used.		
Aillis			
	They learn to read the programming in Arduino		
	Students assemble the components of the weather station		
Skills	In reverse engineering students investigate the working principle of some sensors.		
	In programming the Arduino we provide the programming example for the rain gauge (pluviometer) sensor and learn how it works, how they can change the program and how to observe the measurements		
	Afterwards the students can copy the complete program of the weather station into the arduino, and test it.		
	They assemble the weather station.		
Duration	Reverse engineering : 50 minutes		
	Assembling the components : 80 minutes		
	Programming Arduino : 150 minutes		
Resources	Arduino uno (SparkFun : DEV-11021) (2018- 30 euro)		
	Weather shield (SparkFun: DEV-13956) (barometric pressure, relative humidity, luminosity and temperature) (2018 – 48 euro)		
	2 PRT-00132 + 2 PRT-11417		
	Weather meter (SparkFun: SEN-08942) (2018-90 euro) (weathervane - rain gauge (pluviometer) – anemometer)		
	computer – internet		



INTRODUCTION INTO THE WEATHER STATION

To be able to observe the weather conditions and start predicting weather we want to study a weather station.

A weather station is a device, either on land or sea, with instruments and equipment for measuring atmospheric conditions in order to provide information for weather forecasts and to study the weather and climate.

The measurements taken by our weather station include temperature, atmospheric pressure, humidity, wind speed, wind direction, luminosity and rainfall.





REVERSE ENGINEERING

For this project we will be using a weather meter from the SparkFun website (SparkFun: SEN-08942) When looking at the weather meter we see different sensors.



Activity 2

In this part we will do some reverse engineering. This is the process of extracting knowledge or design information from a product. The process often involves disassembling something and analysing its components and workings in detail.

Let's have a look at some sensors.

The anemometer



What is the purpose of this sensor?

4

.....



To investigate how it works we have disassembled it for you. The following pictures show this process.



Inside the case there is only one component. This a called a reed switch.



Look up the function of this switch. When does it switch?

.....

Inside the rotating head of the anemometer is a small component that makes the switch close for every rotation the head makes. Which component is mounted in the rotating head?

.....

A wind speed of 2.4 km/h causes the switch to close once a second.

The weathervane



With this sensor we can determine the wind direction. A weathervane "points" in the direction **from which the wind is blowing**.



Have a look at the casing of this sensor. Which letters do you find?

With this knowledge, how do you place the weather station in a correct manner?

.....

.....

When opening the case we find the following components:





We recognize the reed switches again, consequently there will also be a magnet in the rotating head of the vane.

How does the sensor determine the direction of the wind?

What will be the accuracy of this sensor? How can you know?

.....

.....



The rain gauge (pluviometer)

To determine the rainfall we can use the rain gauge or pluviometer.



In the pictures shown below you can see the internal construction of the rain gauge.



Describe how the rain gauge is able to measure rainfall.



What determines the accuracy of the rain gauge?

What could you change to improve accuracy?	

Activity 3

How would you build a sensor for measuring snowfall? Make a small design and present it to your class.



ASSEMBLING THE WEATHER STATION

Assembling the weather meter (SparkFun: SEN-08942)



1. Assemble the two metal tubes. They fit into each other.

2. Add the armature to the top of the tube set. Line up the nub on the armature with the notch in the tube. Use one of the included screws and nuts to lock it in place.



3. Mount the anemometer on one side of the armature. The nub on the anemometer matches notches in the armature. Slide the anemometer onto the armature until it locks in place. Use an included screw and nut to lock the sensor in place.





4. Follow the same procedure to install the anemometer on the other side of the armature.

5. Attach the secondary armature to the metal tube using the attached screws and nuts. Assemble the two halves piece with the metal tube in between. Once you have it located where the rain gauge will be clear of the anemometer and weathervane, tighten it into place.



6. Also the rain gauge has notches to ensure it mounts onto the armature. Line these up, and push the rain gauge into place. Again use a small screw to secure the rain gauge in place.



7. On the bottom side of the armature, you will see clips to hold the wires in place. Slide the wire from each sensor into those clips.



8. Plug the anemometer cable into the weathervane. Run the weathervane wire and rain gauge wire down the metal tubes, and use the included zip ties to secure them. You can use the included gear clamps to help mount and secure your meter to e.g. a PVC pipe.

Assembling the weather shield – arduino – weather meter

For our weather station we also use an Arduino Uno (SparkFun DEV-11021) and an Arduino weather shield (SparkFun: DEV-13956), 2 RJ11, 6-pinconnectors and 2 header kits.



The Arduino Weather Shield from SparkFun is an easy-to-use Arduino shield that grants you access to barometric pressure, relative humidity, luminosity, and temperature. The Weather shield



can operate from 3V to 10V, has a humidity accuracy of $\pm 2\%$, a pressure accuracy of ± 50 Pa and a temperature accuracy of ± 0.3 C

Solder the two RJ11 connectors on the weather shield to hook up the rain and wind sensors. Solder the header kits to the weathershield. Now you can fix the shield onto the Arduino. So now everything is ready to program.



Now the hardware of the weather station is almost ready.





PROGRAMMING THE WEATHER STATION

In this part we will have a look at the programming of the weather station. First of all we have a look at the program of the rain gauge (pluviometer) sensor and learn how it works. At the end we will compose the final program and test it.

Using Arduino

When using Arduino for the first time, you need to execute all steps mentioned in the link below in order to make the Arduino platform "ready for use".

https://www.arduino.cc/en/Guide/HomePage

Underneath you see the work screen build-up. It consists of a programming part and a visualisation part.



Then connect the weather station to your computer.

Programming the rain gauge (pluviometer)



We have seen that there is a container that flips over when a certain amount of water has dripped into it.



Activity 5

Determine the amount of water that makes the container flip over. Use a syringe with content indication to pour water into the container and use the serial monitor to determine when it flips over. Repeat this test 10 times and take the average value.

Use the program (Raingauge_one) underneath to determine when the container flips over.

```
const byte RAIN = 2; //pin for rainmeter
volatile unsigned long raintime, rainlast, raininterval, rain, TipAmount;
// volatiles are subject to modification by IRQs
void setup()
{
   Serial.begin(9600);
   pinMode(RAIN, INPUT_PULLUP);
   attachInterrupt(0, rainIRQ, FALLING);
       // attach external interrupt pins to IRQ functions
   interrupts();
                                           // turn on interrupts
}
void loop()
{
}
void rainIRQ() // Activated by the magnet and reed switch in the rain
gauge
{
   raintime = millis();
                                          // grab current time
   raininterval = raintime - rainlast;
       // calculate interval between this and last event
    if (raininterval > 10)
       // ignore switch-bounce glitches less than 10mS after initial edge
    {
       TipAmount = TipAmount+1;
                                              // count new flip
       Serial.print("The bucket has flipped. "); //notify user
       Serial.println(TipAmount);
       rainlast = raintime;
                                          // set up for next event
    }
}
```

Amount of water in one container[I] =

Now determine a formula which calculates the amount of rainfall/m² that one container represents:

The surface area of the top surface of the rain gauge[m²]:



Amount of rainfall per square meter [I/m²] that one container represents =

```
In the program below (Raingauge_two), fill in the calculated value into the variable
"VolumeSquareMeter" and test the program.
const byte RAIN = 2; //pin for rainmeter
float waterAmount = 0;
float VolumeSquareMeter = 0.71637; // <= Fill in the volume here</pre>
volatile unsigned long raintime, rainlast, raininterval, rain;
// volatiles are subject to modification by IRQs
void setup()
{
   Serial.begin(9600);
   pinMode(RAIN, INPUT PULLUP);
                                             // input from wind meters rain
qauge sensor
   attachInterrupt(0, rainIRQ, FALLING);
                                                // attach external interrupt
pins to IRQ functions
                                                // turn on interrupts
  interrupts();
}
void loop()
{
}
void rainIRQ()
// Activated by the magnet and reed switch in the rain gauge
{
   raintime = millis();
                                            // grab current time
   raininterval = raintime - rainlast;
       // calculate interval between this and last event
    if (raininterval > 10)
       // ignore switch-bounce glitches less than 10mS after initial edge
    {
        waterAmount = waterAmount + VolumeSquareMeter;
       Serial.print("Total rainfall = ");
        Serial.print(waterAmount);
        Serial.println(" l/m^2");
       rainlast = raintime;
                                          // set up for next event
    }
}
```



Exploring the program of the entire weather station

To be able to use all sensors you will need to install two libraries. Go to this link and then to "libraries and the Arduino web editor" (marked in yellow).

https://create.arduino.cc/projecthub/Arduino_Genuino/getting-started-with-arduino-web-editoron-various-platforms-4b3e4a



You can find the two libraries in the folder "libraries" provided with this project.

Now upload the program (final_program) and you are ready to explore the weather station. The flow chart on the next page shows how the program works.







First look for the illuminance sensor underneath the text "Light" on the weather shield.

Activity 6
Run the program and use a light source to explore the illuminance sensor.
What do you notice in the serial monitor?
Translate the English phrases in the program into your own language. Upload it and
see if it works.
Now we will take a look at the wind vane.

Activity 7

Look for the letters on the wind vane.

Run the program and check the result in the serial monitor.

Now use a compass to orientate the wind vane in the right position so that the North is really North.

Finally we will observe the anemometer.

Activity 8

Run the program and spin the anemometer to see what happens.

Try who can blow the hardest and make the anemometer spin really fast.

Look up on the internet how hard the wind can blow in your area.



Our weather station and the world

There are many ways to keep track of the values of the weather station. It is simple to write a program in MIT App Inventor that allows you to use Bluetooth to send the values to your mobile phone. Or you can use an RPi to send the values to an online platform like wunderground (<u>https://www.wunderground.com/</u>).

This would lead us too far, but for whoever is really interested, you can see underneath what this could lead to.



Smartphone/Bluetooth

Weather History Graph May 16, 2018 - May 21, 2018



Wunderground/RPi



P	Α	R	T.	2

Торіс	Weather station		
Subjects	Science, Technology, Art, Engineering		
Level	$\bigstar \bigstar \bigstar$		
Aims	Students build their own instrument shelter for protecting the electronic components and learn about the placement of the weather station.		
Skills	In this part the students learn about the influence of the placement on measuring wind speed, rain, They learn what is important to build a shelter for the electronic components.		
Duration	Depends on construction		
Resources	Depends on construction		



PLACEMENT OF THE WEATHER STATION

Introduction

The goal of installing a weather station on or near a house is to monitor the change of the weather, which also allows us to anticipate some weather changes in advance.

If such a weather station can be connected via modems, we can monitor and register remote information about weather at different locations. Such data are not only interesting, but can also offer information about weather changes in a wider area and therefore is a good base for predicting the weather.

Monitoring such data from different locations is also a good and well-founded basis for the current climate change warning. It is quite different, more substantiated and exciting if we discuss this on the basis of the data. Considering the fact that there are a lot of such weather stations which could be integrated into the joint application in the European as well as in the broader field, these data are already very representative information about weather phenomena.

Positioning of sensors

The content elements of such a weather station are, first of all, sensors that are recording data on air temperature, air humidity, air pressure, direction and intensity of the wind, precipitation. The sensors must be connected to the control console, which could also have an LCD display for displaying data. The connection between the sensors and the console can be wireless or made through conductors. The console can also provide a connection with a smartphone and access data from a remote location on the basis of the appropriate application. The system can be powered by the electrical network or can have its own autonomous battery. Such a battery can be powered by a solar cell.

Appropriate positioning of the sensors is important for the proper functioning of the weather station.

- The temperature sensor must be at least 2 m from the ground and at least 30 m if the ground is paved. It has to be positioned away from the structures for at least four times their height; the sensor must also be well protected against direct sunshine.

- The wind sensor should be 10 m above the ground and not closer to objects than 10 times the height of the object. It is useful to mount it on the roof of a building.

- It is best to mount the precipitation sensor together with the wind sensor.

- It is most helpful if the sensors for temperature, air pressure and humidity are placed in the instrument shelter, while the wind and precipitation sensors are on the roof.



An example of a weather station:



Building an instrument shelter

An example of sensors placement:



Activity 1

Make a shelter for the placement of the arduino, the weather shield, battery,....

Measure all the objects that you have to place in the station.



Activity 2

Design and make a shelter. You can use your own creativity. But the instrument shelter must ensure free air flow and protection against direct sun rays. The examples below serve to give you some inspiration.



Classic instrument shelter

Modern design instrument shelter



In the link below you see the building instructions of the modern design https://drive.google.com/file/d/1rcIWZGKQCHVz6gS8agidW484kcm-_FRI/view

Simple design of an instrument shelter





Торіс	Weather station		
Subjects	Mathematics, Science, Technology		
Level	* * *		
Aims	Students measure the different weather elements and make graphs and study the weather during a day, a month,		
Skills	In this part the students use the weatherstation to learn about the weather conditions.		
Duration	Depends on measurements		
Resources	The weather station connected to a pc or laptop		



HOW IS THE WEATHER?

Activity 1

Connect the weather station to a laptop or PC and read the different values.

Which values do you read?		
Date:		
Time :		
APPLIANCE	VALUE	UNIT
rain gauge (pluviometer)		
pressure		
illuminance		
humidity sensor		
weathervane		
temperature sensor		
anemometer		

Activity 2

Look for a weather station in your area, using the website <u>www.wunderground.com</u>. Compare your results to those of the online weather station.

	Our values	Wunderground	UNIT
rain gauge (pluviometer)			
pressure			
illuminance			
humidity sensor			
weathervane			
temperature sensor			
anemometer			

If there are any differences, what could be the cause?



Look for a couple of official weather sites and compare your results to those of the official weather sites.

	Our values	Site 1:	Site 2:	
rain gauge (pluviometer)				
pressure				
illuminance				
humidity sensor				
weathervane				
temperature sensor				
anemometer				

If there are any differences, what could be the cause?

Activity 3

For one day long, record the measurements every hour of the day and make a chart on temperature, humidity and rainfall.



PART 4		
Торіс	In this lesson we study solar and lunar eclipses and calculate the height of a mountain on the Moon.	
Subjects	Mathematics, Science, Technology, Geography, Art	
Level	$\bigstar \bigstar \bigstar$	
Aims	The students learn about eclipses and observe a solar or moon eclipse. The students learn to use websites to observe the Moon. They use mathematical measurements and calculations to learn about the height of mountains on the Moon.	
Skills	 observing natural phenomena applying mathematical skills about trigonometry and interpolation data search on the internet 	
Duration	50 minutes (lesson about eclipses) 100 minutes (calculation height of mountain)	
Resources	internet – Google Moon – calculator - ruler	



THE SUN – THE MOON – THE EARTH

Introduction

Since a moon eclipse occurs during our international project and since Wargentin was an astronomer, we thought we really had to study this phenomenon in some more detail. But before starting, we would like to look into our solar system and its size.

Activity '

Conduct an internet search and try to find these sizes and distances.

Sun radius	km
Earth radius	km
Moon radius	km
average distance Earth - Moon	km
average distance Earth - Sun	km

Suppose we want to make a drawing of our solar system. Then we need to determine a scale for our drawing. Suppose we take 1 mm as the radius of the Moon. Now calculate all the other sizes and distances.

Sun radius	cm
Earth radius	cm
Moon radius	0.1 cm
average distance Earth - Moon	cm
average distance Earth - Sun	cm

Is it possible to make a correct drawing if we want to include Sun, Moon and Earth in the same drawing? Yes / No

Why (not)?

The radius of the Earth is times the radius of the Moon. The radius of the Sun is times the radius of the Earth.

Moreover, the distance from the Earth to the Sun is about times the distance from the Earth to the Moon.



Visibility of an object

A light source emits light and this way creates a shadow behind large objects An object is visible to an observer when it emits light itself, or when it reflects light from a light source.

On the drawing below you can see how an object reflects light from a light source and is therefore visible to the observer. The line "Object-Observer" demonstrates this on the drawing.



Activity 2

Explore the app a little and reposition the light source, the object and the observer in order to discover when the object will be visible to the observer or not. http://seilias.gr/erasmus/html5/shadow/shadow.html

Total Solar and Lunar eclipse

Solar eclipses occur at New Moon, when Sun-Moon-Earth are in one line. Moon and Earth however don't move in the same plane around the Sun. That's why there is no solar eclipse at every New Moon.

A total solar eclipse can only be observed from within a small area on the Earth. This is the area that is in the core shadow (umbra) of the Moon. Areas on Earth that are in the penumbra experience a partial solar eclipse.





Lunar eclipses only occur at Full Moon, when Sun-Earth-Moon are in one line. Moon and Earth however don't move in the same plane around the Sun. That's why there is no lunar eclipse at every Full Moon.

Lunar eclipses can observed from any place on Earth where night has fallen.

When the Moon passes through the penumbra of the Earth, the Full Moon will only be a little darker. A total lunar eclipse will occur when the entire Moon passes through the core shadow (umbra) of the Earth. During a total lunar eclipse the moon doesn't completely darken, but gets a red shade.

If only part of the Moon passes through the core shadow (umbra), we observe a partial lunar eclipse.



Activity 3

Explore the app a little and reposition the Sun, the Moon and the Earth and create your own solar and lunar eclipses. <u>http://seilias.gr/erasmus/html5/eclipse/eclipse.html</u>

In order to create an even more realistic representation we have made a third app. Eclipses are no 2-dimensional but 3-dimensional phenomena. Consequently the core shadow (umbra) is not a triangle, but a cone. In the 2-dimensional drawing above, it looks as if the Moon is in the shadow of the Earth. But in reality this might not be the case. The Moon's position might be behind or even in front of the cone shaped shadow. And therefore there may be no lunar eclipse.

That's why the 3D-app gives you a more accurate representation of the eclipse. In the top left hand corner it will also show you how the eclipse will appear to us.





Activity 4

Explore the app a little and create your own lunar eclipse. http://seilias.gr/erasmus/html5/eclipse3D/eclipse3D.html

Observing a solar and lunar eclipse

In the course of a year you have the opportunity to see two to five solar or lunar eclipses. The number of the one, influences the number of the other. Four is the minimum number of eclipses we can see in one year. This would be two solar and two lunar eclipses.

At most we can see seven eclipses in one year. This could be two solar and five lunar eclipses, three solar and four lunar eclipses, four solar and three lunar eclipses or five solar and two lunar eclipses.

When you watch a solar eclipse you have to be careful though. Always use a pair of eclipse glasses or construct your own eclipse viewer.

https://www.youtube.com/watch?v=PMPBWLSYKaw

Activity 5

Check on <u>https://eclipse.gsfc.nasa.gov/LEcat5/LE2001-2100.html</u> how many total lunar eclipses there are in the 21st century.

When is the next total lunar eclipse?

Will you be able to see it?

If so, take a fantastic picture.



THE HEIGHT OF A MOON MOUNTAIN

Introduction

In order to calculate the height of a mountain on the moon we need a picture with 2 clearly recognizable places on the moon, a mountain but also the precise time at which the picture was taken. On that picture we should clearly see the shadow of the mountain of which we want to calculate the height.

In the left hand image underneath you see the crater Wargentin. It is an unusual crater because it has the form of an elevated platform because at the time of its formation the crater filled with lava.

On the right hand side you see the crater Walther. At its centre you notice a mountain with a shadow. This is the case with most large diameter craters. At the end of this lesson you will be able to calculate the approximate height of the mountain.



Calculating the scale of the picture





You can look up the coordinates of the recognizable places on Google Earth. When you open Google Earth, the tool bar at the top will show a planet icon. When you click it, you will be able to change the image to the Moon.



Thanks to Google Moon we can determine the distance between two recognizable positions. In this example it is 122 km.



We measure the distance between the two recognizable positions in the picture and can this way determine the scale of the picture. The distance in this picture is 9.7 cm. This means that 1 cm equals 12.58 km.



Activity 1

Take the picture you get. In this picture you see a moon crater with a mountain that has a nice shadow. This crater is "Walther".

Look up this crater, using

https://planetarynames.wr.usgs.gov/Page/MOON/target

Click on "crater" and next on "Refine your search". In this tab you can choose "Feature Name" and fill in "Walther". Then click on "Search" at the bottom.

Determine the coordinates of the foot of the Moon mountain. Also have a look at the pdf file under "Quad". This will show you an even better map of the area.

Use Google Moon to determine the diameter of crater "Werner", located some way right of and above "Walther". It's a nice circular crater.

Check the answer using

https://planetarynames.wr.usgs.gov/Page/MOON/target

https://www.lpi.usra.edu/lunar/tools/lunardistancecalc/index.shtml

Measure the diameter of the crater in the picture.

What is the scale of the picture?



Determine the position of the Terminator at the time of the picture

The Terminator is the line that separates the illuminated and dark side of the moon. This line continuously changes its location during the movement of the Moon around the Earth.



In what follows we want to try and establish the location of the Terminator on the day the picture was taken.

In our case we know that the picture was taken on 6 September 3.30 UT or GMT. There are tables like the one underneath.

	Datum	op komst		doorgang		ondergang		k	term.
		h	m	h	m	h	m		
	1/sep	19	29	1	17	7	33	0,95	-71,5
Terminator 🛛 🔼	2/sep	19	41	2	2	8	52	0,9	-59,3
	3/sep	19	54	2	46	10	10	0,83	-47,1
	4/sep	20	11	3	31	11	27	0,75	-34,9
	5/sep	20	32	4	17	12	43	0,66	-22,7
4. (c)	6/sep	21	0	5	6	13	55	0,56	-10,5
	7/sep	21	39	5	55	15	1	0,47	1,7
	8/sep	22	31	6	46	15	55	0,37	13,1
	9/sep	23	34	7	38	16	37	0,28	26,1
	10/sep	_	_	8	28	17	8	0,2	38,3

This table shows you the longitude of the position of the Terminator on every day at 0.00 UT. As you can see in the red boxes the Terminator moves from 6 till 7 September from -10.5° to $+1.7^{\circ}$. This means that the moon rotates over an angle of 12.2° in 24 hours, or over an angle of 0.508° each hour. In this table a negative angle means that the shadow line lies on the easterly hemisphere of the moon, a positive angle means that it lies on the westerly hemisphere or in other words has a westerly longitude.



With these data we can calculate the position of the Terminator at the moment the picture was taken

To do this we use this formula:

 $\alpha_{\text{terminator}} = \alpha_0 + (\Delta \alpha * \Delta t)$

 $\alpha_{terminator}$ [°] : longitude of the Terminator at the time of the picture

 α_0 [°] : longitude of the Terminator at the time 0.00 UT on the day the picture was taken

 $\Delta \alpha$ [°/hour] : angle in degrees that the Terminator moves in 1 hour

 Δt [hour] : difference in time between 0.00 UT and the moment at which the picture was taken

Our picture was taken at 3.30 U.T. $\alpha_{terminator} = -10.5+(0.508^*3.5) = -8.7^{\circ}$

Consequently the Terminator is located on the easterly hemisphere of the lunar globe.

Activity 2

At what time was the picture taken?

Position of Terminator on this day and the next.

_	datum	op- komst	az. opk.	door- gang	hoogte	onder- gang	az. ond.	k	Term	1	ь	positie (w a	are eq.) δ	afstand
		h m	Ser all	has	1 214	Je m	-		the state	UT PARTY		b m	* *	km
z	. Japan.	9 27	113,9	14 20	23,4	19 19	248,2	0.07	-53.5	+5,3	-2.6	20 54,9	-15 20	39129
T	2 gen	9 57	108,4	15 09	26,8	20 28	254,2	0.13	-41.3	+5.7	-1.2	21 46.5	-12 29	38785
⊆	3:00	10 25	102,1	15 57	30,8	21 40	261,1	0,21	-29,2	+5,9	+0,3	22 37.7	- 8 58	38424
2	4 100	10 51	95,1	16 46	35,2	22 53	268,5	0.31	-17.0	+5.9	+1.8	23 28,7	- 4 57	38049
	Si sun	11 16	87,8	17 36	39,8			0,41	- 4,8	+5,6	+3,3	0 20,0	- 0 38	37666
	6 900	11 43	80,5	18 27	44,4	0.08	276.1	0.52	+ 7.3	+5.0	+4.6	1 122	+ 3 49	37290
	7 gan	12 12	73,4	19 20	48,6	1 24	283.5	0.63	+19,5	+4.1	+5,6	2 06,1	+ 8 09	36940
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	10 jan	14 15	59,1	22 16	56,2	5 12	300,0	0,91	+55,9	-0,2	+6,5	5 01,1	+17 41	36328
е							Pos	sition	Term	inator	r at 0.	00 U.T		
te	9. gan 10 jan	14 15	59,1	21 13 22 16	56,2	3 30 5 12	Po:	sition	Term	inator	+6,5 +6,5	5 01,1	+15 22 +17 41	



Consequently the Terminator moves	per day or	per hour.						
Δα=								
$\Delta t =$								
Where was the Terminator at the time of the picture?								
$\alpha_{\text{terminator}} = \alpha_0 + (\Delta \alpha * \Delta t)$								
$\alpha_{terminator} =$								
TheTerminator is located on the You can check this by entering the time on http://www.lunar-occultations.com/rlo/epheme	hemisphere of the leave	lunar globe.						
Under "selenographic longitude of terminator" you should find approximately the same number, but with an opposite value.								

Determining the coordinates of the location on the moon to which the Sun is perpendicular at the time of the picture.

Now that we have determined that the Terminator is at -8.7 °, we can calculate the angle under which the Sun is perpendicular to the Terminator : $-8.7^{\circ} + 90^{\circ} = 81.3^{\circ}$

So at the time of the picture the Sun will be perpendicular to a location on the Moon with longitude 81.3°W. The Sun moves in a plane that does not deviate much from the equatorial plane of the Moon. Therefore we choose 0° as the latitude of that location.

So the Sun is perpendicular to the location (0°N, 81.3° W).

Activity 3

To which location on the Moon was the Sun perpendicular at the time of your picture?

Longitude :

Location :



Calculating the angular distance between the location of the Moon mountain and the location where the Sun is in the zenith position

Since we assume that the Sun is always in the zenith position above the Moon equator at noon the formula of spherical trigonometry will be much simplified.

 $\boldsymbol{\delta}$ is the angular distance between two locations on a sphere

 x_A and y_A are the coordinates (latitude, longitude) of the Moon mountain (47° N, 2°W)

 x_B and y_B are the coordinates (latitude, longitude) of the location on the Moon to which the Sun is perpendicular at the time of the picture.(0° N,81.3°O)

 $\cos \delta = \cos x_A \cos(|y_B - y_A|)$

 $\cos \delta = \cos (47^{\circ}) \cos (|81.3^{\circ} - (-2)^{\circ}|)$ $\delta = 82^{\circ} 43' 31.554"$

This allows us to calculate the height of the Sun at the mountain location at the time of the picture. $\alpha = 90^{\circ} - \delta = 7^{\circ} 16' 28.446''$

Activity 4

Location mountain activity 1 : $(x_A, y_A) =$

Location activity 3 : $(x_B, y_B) =$

 $\cos \delta = \cos x_A \cos(|y_B - y_A|)$

δ =

Calculate the height of the Sun at the location of the mountain in your picture.

α = |90° - δ |=



Height of the Moon mountain



Above you see a simple drawing in which h represents the height of the Moon mountain, S the length of the shadow and alfa the angle that we have just determined.

Height = length of shadow * tan (height of Sun)

We measure the length of the shadow of the mountain in the picture; The shadow has a length of 1.8 cm. So in reality it will be 22.64 km.

22,64*tan (7° 16' 28.446") = 2,890

The Moon mountain is 2,890 m high.

Activity 5

Measure the length of the shadow of your Moon mountain in the picture.

Using the scale of the picture, calculate the real length of the shadow.

Calculate the height of the mountain using the height of the Sun from the previous activity and the length of the shadow of the mountain. Use the tangent formula.

Does this answer seem plausible to you?



Appendix



Maan terminator van Regiomontanus tot Stöffler Datum 5 januari 2017 Tijd 17.31u UT (GMT) © Geert Vandenbulcke



