



DFDS Crown Seaways photographed from the beach at “Udsholt Strand” (Udsholt beach).
Question: Is it really behind the horizon?

Eratosthenes, the Greek astronomer and mathematician 276-195 BC, calculated the Earth's circumference to be between 39,060 - 40,320 km = radius 6.317 km. He Since confirmed by a number of methods to be on average 6.371 km. He assumed that the sun was so far away that the sun's light in principle hit the earth parallel. Source: <https://en.wikipedia.org/wiki/Eratosthenes>.

Mere info

Generelt Billedstil Exif TIFF

Lysstyrkeværdi 10,162
Farveområde sRGB
Konfiguration af komponent... 1; 2; 3; 0
Komprimerede bit pr. pixel 4
Kontrast Normal
Specielt gengivet Normal handling
Dato tid digitaliseret 12. jul. 2022 17.35.21
Dato tid original 12. jul. 2022 17.35.21
Digitalt zoomforhold 1
EXIF-version 2.3
Værdi for eksponeringskorr... 0
Eksponeringsfunktion Autoeksponering
Eksponeringsprogram Blændeprioritet
Eksponeringstid 1/1250
Kilde DSC
Blitz Fra, virkede ikke
FlashPix-version 1.0
Blænde 4
Brændvidde 203,2
Brændvidde i 35 mm film 554
Filmfølsomhed (ISO) 100
Specifikation for objektiv 8,8; 220; 2,4; 4
Lyskilde Overskyet
Værdi for maks. blænde 4
Målingsfunktion Mønster
Pixel X mål 5.472
Pixel Y mål 3.648
RecommendedExposureInd... 100
Mætning Normal
Type sceneoptagelse Standard
Scenetype Et direkte fotograferet bil...
SensitivityType Anbefalet eksponeringsi...
Skarphed Normal
Hvidbalance Manuel hvidbalance
Flash-kompensation 0
Billedstabilisering Panorering
Objektivmodel Sony 24-600mm F2.4-4.0

What is the question and how will I find an answer

Question: Is it the horizon that is hiding a part of the ship on the picture?

How to find an answer:

1. Measure the distance to the ship
2. Use Pythagoras theorem to calculate how much of the ship should be behind the horizon
3. Check if it match the observation on the picture.

What I did?

1. I took a picture of the ship when I was at the beach, and wondered if it could confirm the Earth curvature and radius. It seems like some part of the ship is hidden below the waterline. I am pretty sure it's not because the ship is very low in the water or about to sink. So I found another picture to confirm how it's supposed to look in close distance and in normal operations.
2. I asked myself: If the radius of the earth is 6.371 km as postulated, will this explain why the ship is partly hidden below the horizon? I am well aware that I am not calculating the curvature, but only confirming it can explain why some of the ship is hidden.
3. I need to know these numbers to know how much of the ship that will be hidden below the horizon:
 - a. Elevation above sea level of the observation: 4 m (estimated by myself)
 - b. Earth radius: 6.371 km (2.000 year old number and has worked ever since for ships navigation, flight routes and even space travel)
 - c. Distance to ship: 15 km (estimated based on the ships normal sailing routes)
4. Doing a rough calculation with Pythagoras theorem, it looks right. But I would like to check with more data and see if I could confirm the distance.
5. So let's try to find out how much is actually hidden: I can find ships data on the owners website and another photo of the ship where the waterline is visible. About 4-5 m is hidden by the water according to the photo vs the drawing.
6. I measure the viewing angle per pixel of the camera and measure 18 m on the ship to be 94 pixels on the picture. Using trigonometry I calculate the distance to be 15 km. I also looked up the sailing route and it is 12-16 km from the observation point, so that looks promising.
7. It is not very precise using pixels and viewing angles with only 3 pixels per meter. But if the earth radius is 6.371 km, and I observe a ship from 4 m above sea level, and the ship is 15 km away, then 4,8 m will be below the horizon. **Good match with the observation.**

Fun facts: From 2 m above sea, the horizon is only 5 km away. This is why people sitting on sailboats can't see very far. But from 20 m above sea on a large ship, the horizon is 16 km away and you have much more reaction time and distance. This is why the "bridge" and radars is as high as possible on a ship, lighthouses are high up. In the old days, before radar, there was an observation post in the top of the mast. You can look up Columbus Santa Maria.

What's next? To be scientific about it this is just a single confirmation. I could do the same measurement in different directions, from different heights, with other objects like buildings, bridges, wind turbines. Even islands. Things you know the size of and know the distance to. But the most convincing visually would be a big ship, sailing out, over and behind the horizon in one video. Also using other methods like sun shadows, GPS which is actually in 3D, and even interviewing people that uses the curvature in their professional life. To challenge the model, I need another model of the earth that matches ALL the collected data.



Reference photo: DFDS Crown Seaways photographed between Helsingør and Helsingborg. Distance is estimated to be 2 km.

CROWN SEAWAYS ud for Helsingborg d. 14/2-2020. Foto: Kristian Lundgren

TEKNISKE DATA

| | |
|--------------------|--------------------------|
| Længde: | 170,90 m |
| Bredde: | 27,60 m |
| Dybgang: | 6,35 m |
| Service fart: | 16,10 knob |
| HK: | 35.900 |
| Byggeår: | 1994/2003/2005/2008/2014 |
| Passagerer: | 1790 |
| Kabiner: | 630 stk. |
| Biler: | 450 stk. |
| Sømil: | 1,852 km |
| Knob: | 1,852 km/t |
| Distance Kbh-Oslo: | 275 sømil/509 km |
| Tonnage: | 35.498 ton |

TECHNICAL INFORMATION

| | |
|--------------------|--------------------------|
| Length: | 170,9 meters |
| Width: | 27,6 meters |
| Draught: | 6,35 meters |
| Service speed: | 16,1 knots |
| BHP: | 35.900 |
| Build: | 1994/2003/2005/2008/2014 |
| Passengers: | 1790 |
| Cabins: | 630 |
| Cars: | 450 |
| Nautical Mile: | 1,852 km |
| Knots: | 1,852 km/t |
| Distance Cph-Oslo: | 275 sømil/509 km |
| Tonnage: | 35.498 Tons |

170,9 meters is 3.080 pixels on the drawing.

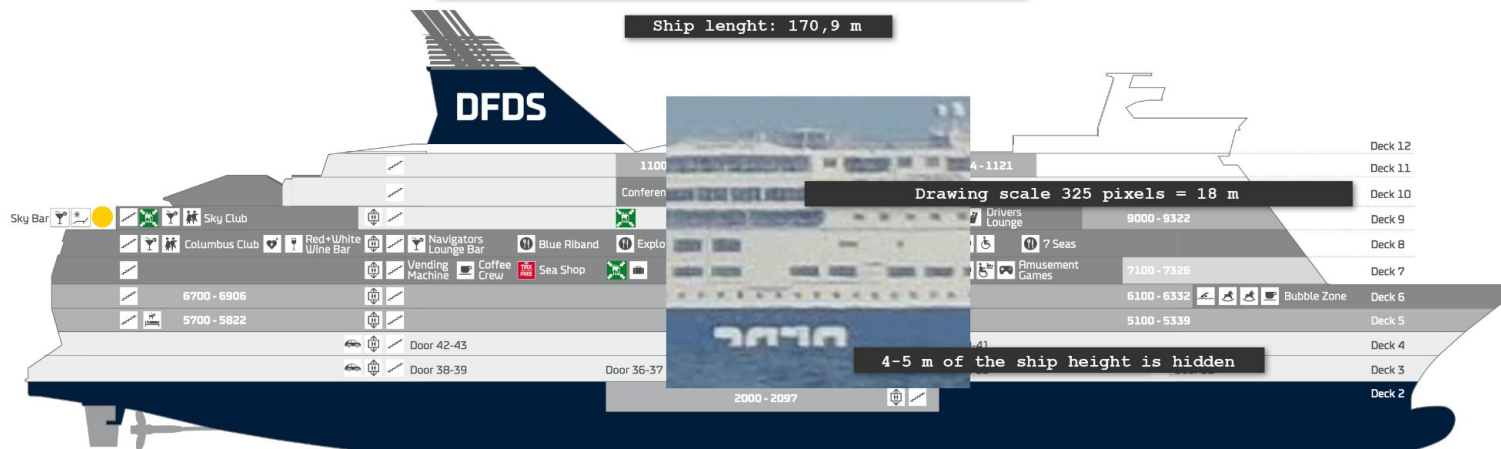
The waterline is between deck 2 and 3.

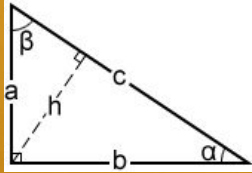
The big white DFDS letters on the side of the ship is cut off 4-5 meters above the waterline.

18 meters of the drawing measures 94 pixels on the photo.

Drawing scale: $170,9 = 3080$ pixels or $1 \text{ m} = 18$ pixels

Ship lenght: 170,9 m





Given $a=23.85$ and $b=699$,
 $c = 699.40676$
 $\angle\alpha = 1.954^\circ = 1^\circ 57' 15'' = 0.034107 \text{ rad}$
 $\angle\beta = 88.046^\circ = 88^\circ 2' 45'' = 1.53669 \text{ rad}$



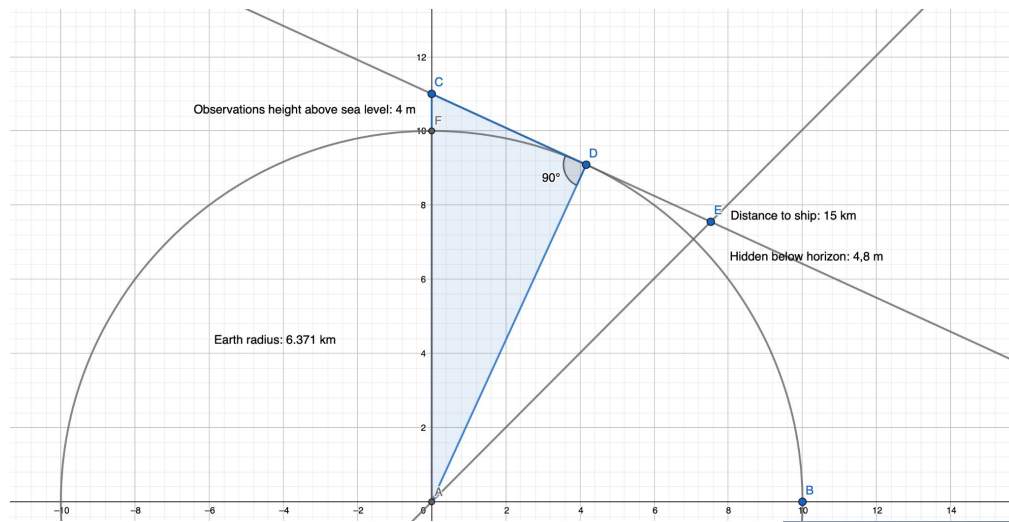
To measure the distance to the ship using the photo, we need the angle per pixel and a known the size of something on the ship. A test shot is made with the same camera and zoom level as the original picture. The size of the ship can be found online and a 18 meter part of the ship measures 94 pixels on the photo.

- Distance from camera sensor to ruler: 699 cm
- Full zoom: 220 mm: width 44,2 cm = viewing angle $3,622^\circ$ (2 x $1,811^\circ$)
- Picture zoom: 203,2 mm: width 47,7 cm = viewing angle $3,908^\circ$ (2 x $1,954^\circ$)
- Picture of ruler dimensions: 5472 x 3648 pixels, dimensions: 1,5:1 or 3:2
- Picture of the ship: 94 pixels = 18 m
- Angle of 94 pixels: $3,908^\circ / 5472 \text{ pixels} \times 94 \text{ pixels} = 0,0671^\circ$ (2 x $0,0336^\circ$)
- Based on 94 pixels the ship is about about 15 km away.

Given $a=9$ and $\angle\alpha=0.03356652^\circ$,
 $b = 15,362.38957$
 $c = 15,362.3922$
 $\angle\beta = 89.966^\circ = 89^\circ 57' 59'' = 1.57021 \text{ rad}$



DFDS Crown Seaways photographed from the beach at Udsholt Strand (Sjælland, Denmark). If you compare this image with another image of the same ship and measure the difference, you will find that 5 meters of the ship is hidden by the water. You can clearly see the letters of the DFDS logo is partly hidden and also half the text at the stern of the ship. The ship's data is available at the DFDS website.



Using Pythagoras Theorem you can calculate the distance to the horizon from a given elevation above sea level. From there you can calculate how much of the ship that will be hidden seen from a given distance. In this example the water will hide 4,8 meters of the ship from a distance of 15 km watched from an elevation of 4 meters. Good match with the observation.



The ships normal route is 12-16 km from the observation point.

| A | B | C | D | E | F | G |
|----------------------------|---------------------------|-------------------------------|-------------------------|----------------------|-----------------------------------|------------------------------|
| Distance to horizon | | | | | | |
| Earth radius (m) | Observation elevation (m) | Diameter plus observation (m) | Distance to horizon (m) | Distance to ship (m) | Distance from horizon to ship (m) | Hidden under the horizon (m) |
| 6.371.000 | 4 | 6.371.004 | 7.139 | 15.000 | 7.861 | 4,8 |

$$=SQRT((C^2)-(A^2))$$

$$=sqrt((A^2)+(F^2))-A$$

Conclusion

The observation of the ship with partly hidden DFDS logo by the water, matched calculation with the following data:

Earth radius: 6.371 km

Distance to ship: 12-16 km

Hidden below the horizon: 4-5 m

Photographed from elevation 4 m above sea level.