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. Since confirmed by a number of methods to be on average 6.371 km. He used the suns shadow to measure the curvature. 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?

How to find an answer:

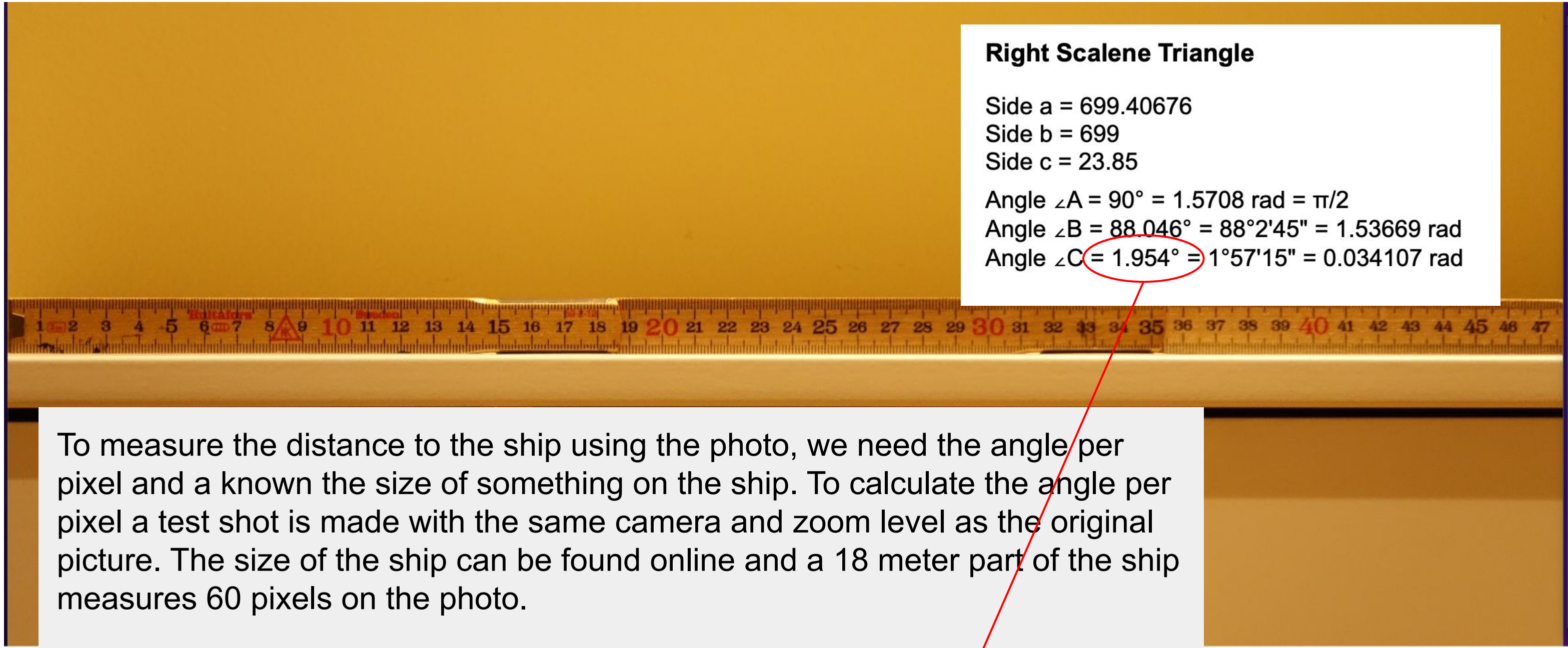
1. Measure the distance to the ship
2. Use Pythagoras theorem to calculate how much of the ship should be behind the horizon
3. Check if it match the observation.

What I did?

1. **I took a picture of the ship when I was at the beach, and wondered if I could confirm the Earth curvature and radius based on that picture. 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 in normal operations.**
2. I asked myself: If the radius of the earth is 6.371 km, will this explain why the ship is partly hidden below the horizon? I was well aware that I was not calculating the curvature, but only confirm it could 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 Google Maps and the ships normal sailing routes)
4. Doing a rough calculation with Pythagoras theorem, it looks right with the numbers. But I would like to check with more data.
5. So let's try to find out how much is actually hidden: I found ships data on the owners website and another photo of the ship where the waterline is visible. About 4 to 4,5 m is hidden by the water.
6. The distance to the ship: I measured the viewing angle per pixel of the camera and measured 18 m on the ship to be 60 pixels on the picture. That calculates to a distance of 16 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 possible to be 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 14,5 km away, then 4,3 m will be below the horizon. **Good match with the observation**.
8. 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.
9. What's next? To be scientific about it, I should 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 shadow.

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

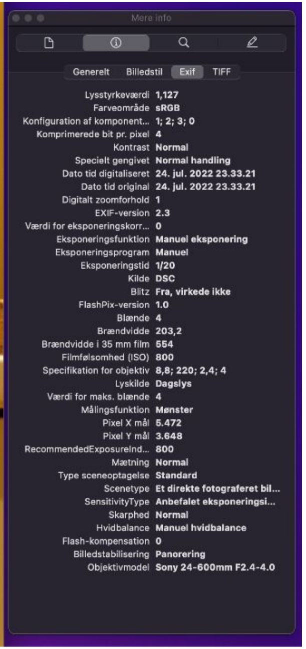
CROWN SEAWAYS ud for Helsingborg d. 14/2-2020. Foto: Kristian Lundgren



Right Scalene Triangle

Side a = 699.40676
Side b = 699
Side c = 23.85

Angle ∠A = 90° = 1.5708 rad = π/2
Angle ∠B = 88.046° = 88°2'45" = 1.53669 rad
Angle ∠C = 1.954° = 1°57'15" = 0.034107 rad



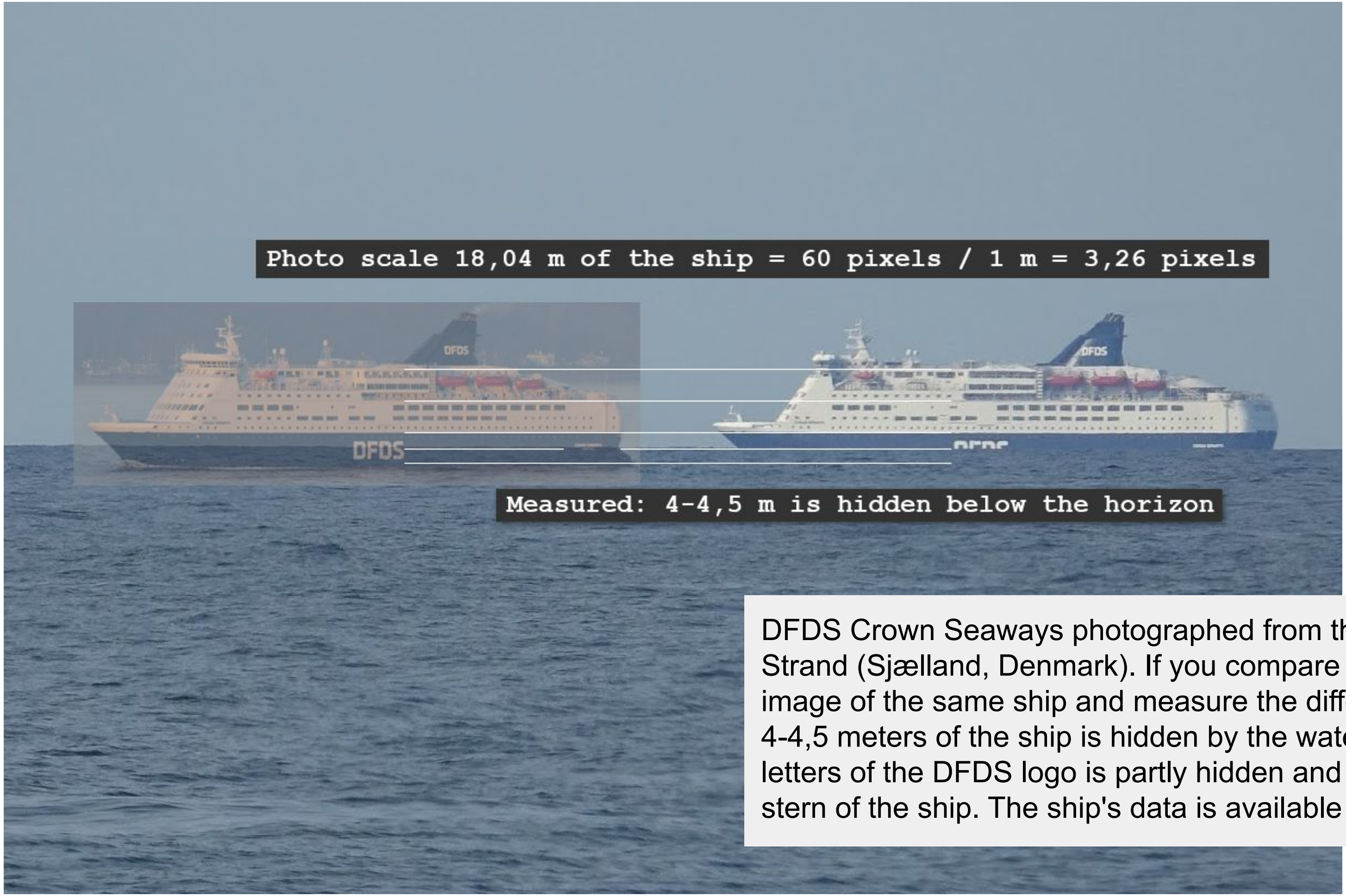
To measure the distance to the ship using the photo, we need the angle per pixel and a known the size of something on the ship. To calculate the angle per pixel a test shot is made with the same camera and zoom level as the original picture. The size of the ship can be found online and a 18 meter part of the ship measures 60 pixels on the photo.

Distance from camera sensor to ruler: 699 cm
Full zoom: 220 mm: width 44,2 cm / angle 3,622° (2 x 1,811°)
Picture zoom: 203,2 mm: width 47,7 cm / angle 3,908° (2 x 1,954°)
Picture of ruler dimensions: 5472 x 3648 pixels / 1,5:1 / 3:2
Picture of the ship: 60 pixels = 18,04 m
Angle of 60 pixels: 3,908° / 3648 pixels x 60 pixels = 0,0643° (2 x 0,0321°)
Based on 60 pixels the ship seems to be about 16 km away.

Right Scalene Triangle

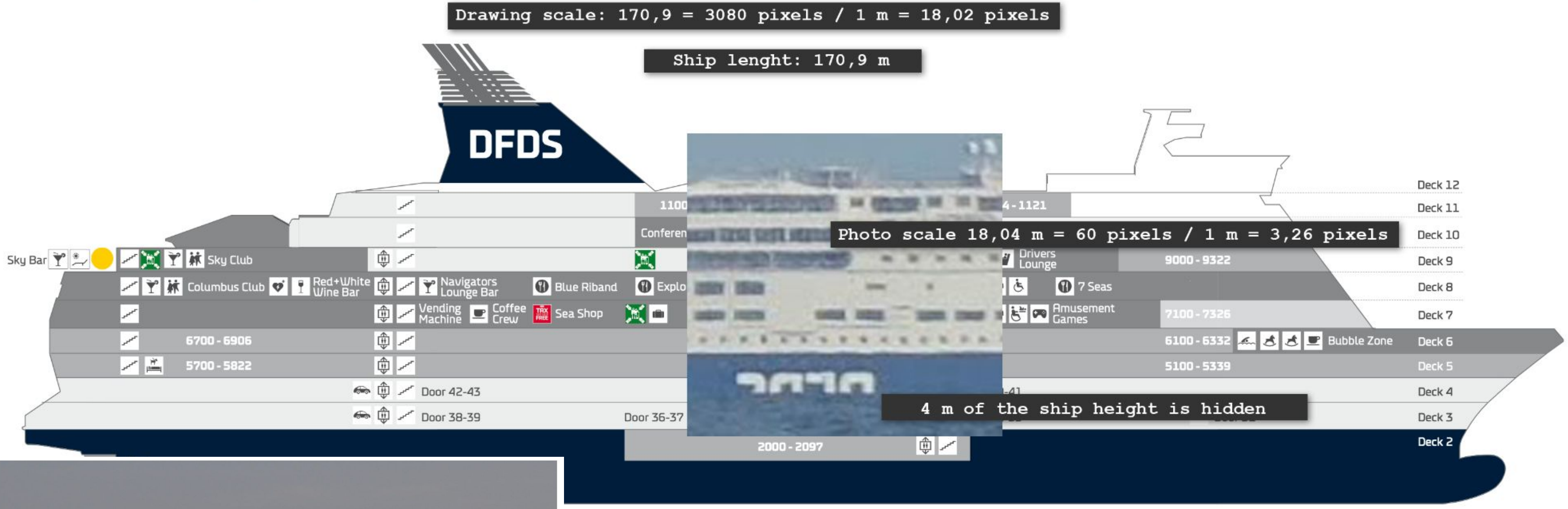
Side a = 16,064.23809
Side b = 16,064.23557
Side c = 9

Angle ∠A = 90° = 1.5708 rad = π/2
Angle ∠B = 89.968° = 89°58'4" = 1.57024 rad
Angle ∠C = 0.0321° = 0°1'56" = 0.00056025 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 4-4,5 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.

https://www.dfds.com/da-dk/passagerfaerger/om-bord/kobenhavn-oslo/skibsoversigt

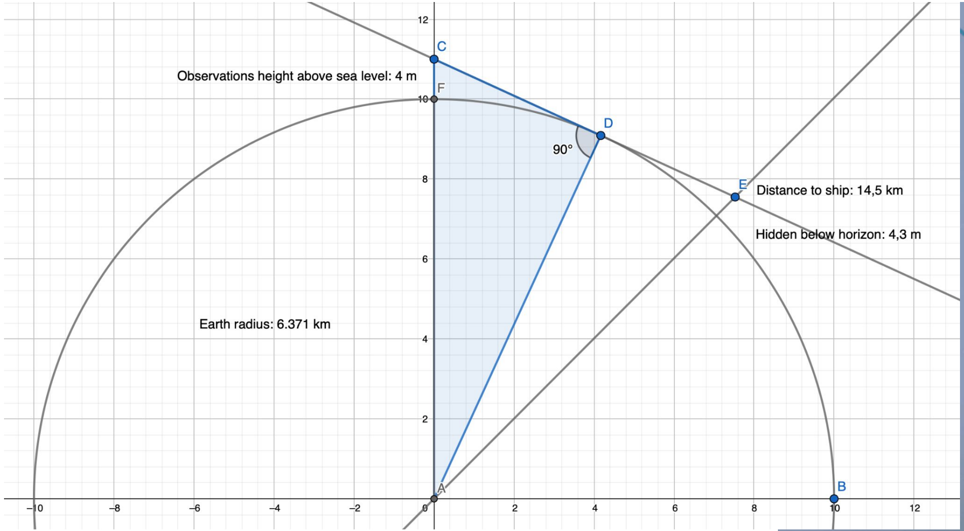


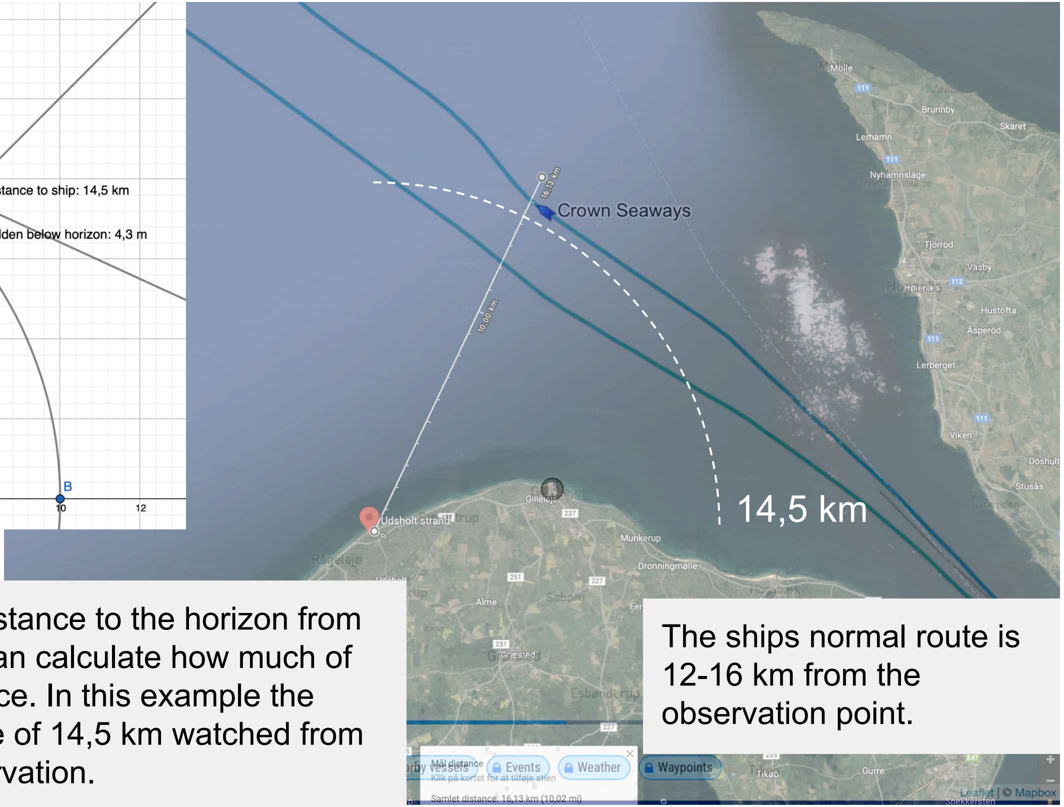
CROWN SEAWAYS ud for Helsingborg d. 14/2-2020. Foto: Kristian Lundgren

The waterline is between deck 2 and 3.

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

18,04 meters of the ship measures 60 pixels on the photo.





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 4,3 meters of the ship from a distance of 14,5 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
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	14.500	7.361	4,3

=SQRT((C2^2)-(A2^2))

=sqrt((A2^2)+(F2^2))-A2

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

Photographed from elevation 4 m above sea level.

Also: We have known this for more than 2.000 years by the work of Eratosthenes and Pythagoras in old Greece.