# On the history of the Secchi disc

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The first records on regular, tabulated, measurements of transparency of natural waters are those performed by the German naturalist Adelbert von Chamisso during the Russian "*Rurik*" Expedition 1815–1818 under the command of Otto von Kotzebue. A standardized method to determine the water clarity (transparency) was adopted at the end of the nineteenth century. This method (lowering a white painted disc into the water until it disappeared out of sight) was described by Pietro Angelo Secchi in *Il Nuovo Cimento* and was published in 1865. The Austrian scientist Josef Roman Lorenz von Liburnau, experimenting with submersible objects, like white discs, in the Gulf of Quarnero (Croatia) in the eighteen-fifties, well before Secchi started his investigations, questioned the naming of the white disc. However, the experiments performed by Secchi and Cialdi in 1864 on such an intensive scale were never performed before. At the beginning of the twentieth century, water transparency observations by means of a 30 cm white disc, was named the Secchi-disc method. [DOI: 10.2971/jeos.2010.10013s]

**Keywords:** Secchi disc, water transparency, history of marine optics

## 1 INTRODUCTION

From the time of Louis Ferdinand de Marsilli (1658–1730) until roughly the beginning of the nineteenth century, sea water was analysed both on its colour and its transparency by visual perception. For a judgement on its transparency sea water was put into a vase and described as misty, turbid or clear accordingly. Throughout history, ship's log, of many ocean explorations, regularly refer to the colour and transparency of seawater.

One of the oldest records describing the transparency of the ocean water (directly connected with its colour) was the one made near Novaya Zemlya by Captain John Wood Jr. (1620–1704), member of the Royal Society and leader of an expedition in search of the Northeast Passage, before he was shipwrecked which dates back to 1676. Years later, a narrative of the expedition was published and written down in collaboration with the English naval commander Sir John Narborough (1637–1688). One of the observations [1], looking overboard into the sea and noticing the ocean floor, has been quoted frequently over the past centuries: "*We sounded and had 80 Fathoms of Water green Oar, at which time we saw the Ground plain, being very smooth water. The Sea Water, about the Ice and the Land, is very salt, and much saltier than any I ever tasted, and a great deal heavier and I may say the clearest in the World, for I could see the ground very plain in 80 Fathoms water and I could see the shells at the bottom very plain.*"

From his frigate, "Speedwell" Wood could see shells at the bottom of the sea at a depth of eighty fathoms or 140 m. Probably what he saw were *Mya truncata* shells (first described by taxonomist Carl Linnaeus (1707–1778) in 1758) [2] on a dark coloured bottom.

It is disappointing that until now Wood's observation never has been confirmed by other oceanographers. Apart from the original paper of Narborough the observation of John Wood can be found in *Histoire Générale Des Voyages* by Jacques Philibert Rousselot de Surgy (1737–1791) [3] and in *Histoire des Naufrages* of 1789 [4].

If the surface of the sea is ruffled, or in state of agitation, it is hard to see the objects below by any instrument which is not immersed in the water. To overcome this problem, David Brewster [5] in 1813, invented a small floating telescope for viewing objects underwater (see Figure 1) that was recognized by the Academy of Sciences at Copenhagen for its great practical utility.

Captains and scientists, exploring the sea, noticed the sea's great ability of transmitting sun rays until great depths. To measure and quantify the transparency of the sea, several methods were described during the nineteenth century and the accounts of methods used by captains or scientists are sketched in a chronological manner in the following chapter.

An illustrated example of the Secchi disc is presented in Figure 2. Luksch, onboard the steamer "*Pola*" crossing the eastern Mediterranean and Red Sea between 1890 and 1898 used this small 45 cm disk [6]. West of Beirut at 33°47′ N and 34°8′ E the disc could be seen at 60 m, in the northern Red Sea until 50 m and in the south only until 39 m.

## 2 HISTORICAL BACKGROUND

It was already under command of the Russian navigator Otto von Kotzebue (1787–1846) on his first exploration trip (1815–1818) in the Bering Sea and looking for a north-eastern pas-

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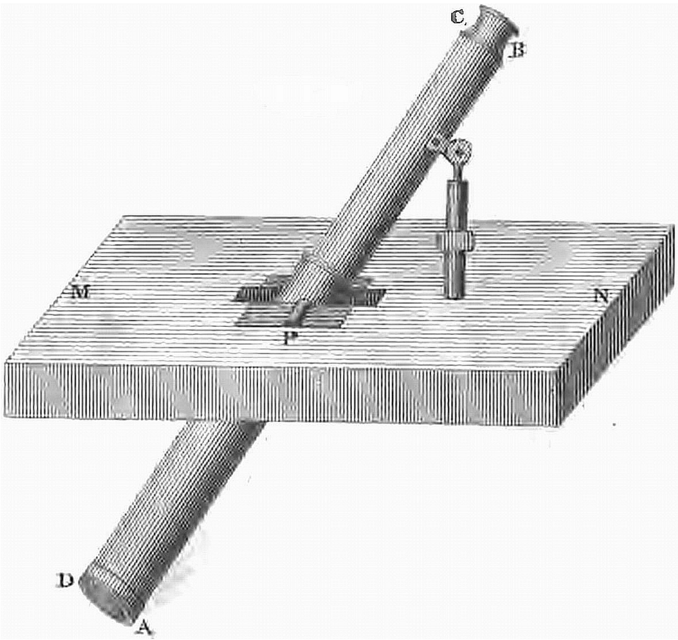


FIG. 1 Brewster's hydraulic tube telescope for viewing objects underwater (1813); *"When the apparatus is plunged into the sea, the floating parallelepiped MN will keep the tube ABCD in a vertical plane, and by moving it around the pivot P, it may be directed to any object under water or at the bottom"* (Reproduced by the author from the original work).

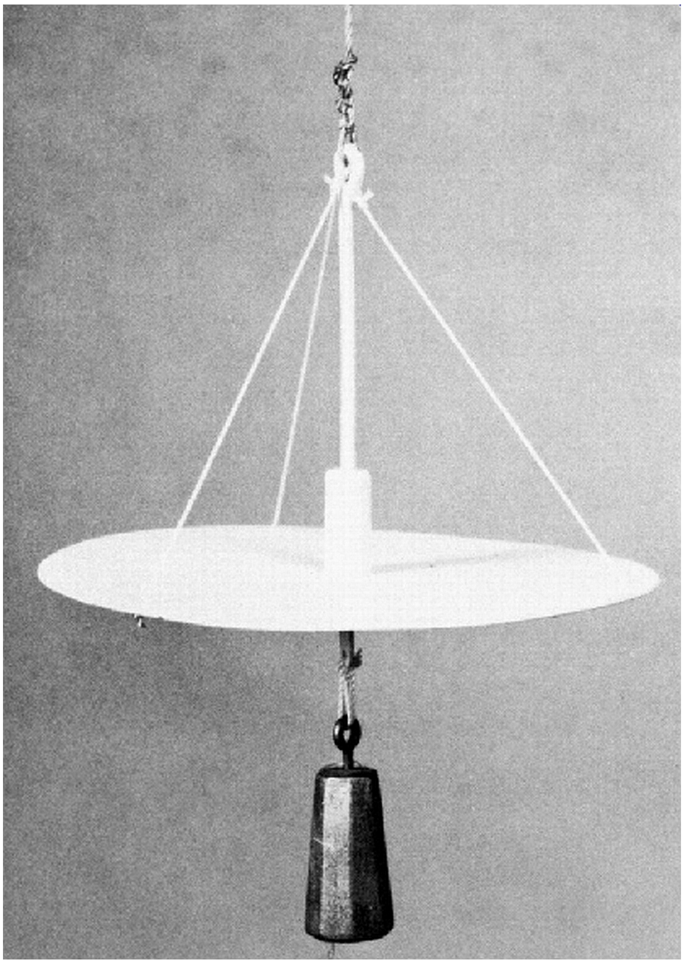

FIG. 2 Luksch polished white painted Secchi disc of 45 cm in diameter used onboard the "*Pola*" around 1890.

sage that transparency measurements were mentioned. On board the "*Rurik*", it was the accompanying German writer and naturalist Adelbert von Chamisso (1781–1838) who used a whitened surface attached to the sounding lead to measure the water transparency [7]: "*The transparency of the sea water would be easiest measured by letting down a flat surface, fastened to the plumb line, painted white, with stripes, or letters of black, or other colour, on it. For want of this, a white earthen plate, or a board covered with white stuff, might be used. The depth at which the board became invisible or the marks upon it undistinguishable in different waters, would show their relative transparency.*"

Some of the observations of Adelbert von Chamisso are depicted in Table 1. In the North Pacific, he experienced that a dinner plate could be seen until a depth of 27 fathoms (49 m) [9]: "*I observed to-day the transparency of the water with a white plate, and found that it was visible at a depth of twenty-seven fathoms: the previous observations of this kind had been made with a piece of red cloth.*"

TEMPERATURE OF THE SEA WATER AT DIFFERENT DEPTHS.

In the Years 1815, 1816, 1817, and 1818.

| Days. | Temperature of the Sea Water: on the Surface. | Temperature of the Sea Water: below the Surface. | Depth in Fathoms. | Temperature of the Air. | The Ship's Latitude. | The Ship's Longitude. | Transparency of the Water in Fathoms. | Observations. |
|---|---|---|---|---|---|---|---|---|
| | | | | | ° ′ | ° ′ | | |
| 1815. | | | | | | | | |
| 15. October | +68.5 | +55.7 | 100 | +71.1 | 39 27 N. | 12 57 W. | 10 | |
| 16. — | +69.1 | 55.0 | 138 | 72.5 | 39 4 | 13 8 | 10 | In the Atlantic Ocean. |
| — | — | 56.0 | 96 | — | — | — | — | |
| 25. — | 74.3 | 56.3 | 196 | 74.3 | 30 12 | 15 14 | 11 | |
| 1816. | | | | | | | | |
| 8. January | 54.9 | 38.8 | 196 | 57.6 | 44 47 S. | 57 31 | 8 | Cape Horn. |
| 7. April morn. | 78.5 | 68.5 | 125 | 79.2 | 18 17 | 124 56 | 13 | |
| — | — | 57.5 | 175 | — | — | — | — | |
| At noon. | 79.6 | 68.0 | 125 | 80.0 | — | — | — | |
| — | — | 54.0 | 200 | — | — | — | — | |
| 13. April | 80.0 | 79.0 | 10 | 79.8 | 15 26 | 133 42 | 13 | In the South Sea. |
| — | — | 79.0 | 20 | — | — | — | — | |
| — | — | 78.8 | 50 | — | — | — | — | |
| — | — | 72.0 | 100 | — | — | — | — | |
| — | — | 56.0 | 200 | — | — | — | — | |
| 12. May | 82.5 | 55.0 | 300 | 83.0 | 1 17 N. | 177 5 | 14 | At the Equator. |
| 1. June | 74.0 | 62.0 | 100 | 75.0 | 29 24 | 199 26 | 10 | |
| — | — | 52.5 | 300 | — | — | — | — | |

E E 2

APPENDIX.

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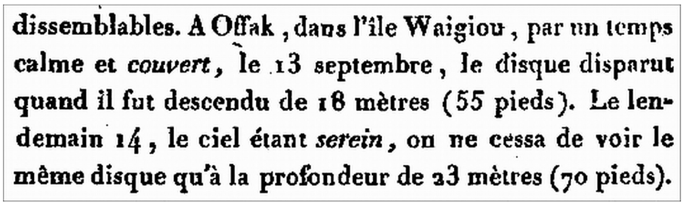
TABLE 1 Observations of the sea surface and air temperature (in degrees Fahrenheit) and of the transparency of the water (in fathoms) measured with a white disc. The observations were collected during the first part of Kotzebue's voyage of discovery during the Atlantic and Pacific crossing.

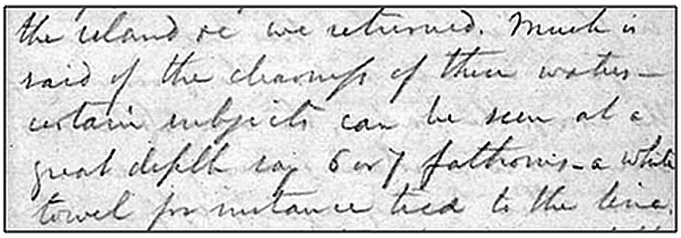
During a French voyage around the world (1822–1825) under the command of Louis Isidore Duperrey (1786–1865) on the corvette "*la Coquille*", a white painted plank, with a diameter of 2 feet and an attached weight, was lowered into the water to measure its transparency [10, 11]. The depths at which the disc disappeared were between 9 m, close to Ascension Island, South Atlantic Ocean and 23 m near Offak, Island of Waigiou, Indonesia (see the French note in Figure 3).

Around 1832, Xavier de Maistre constructed a square iron plate of around 35 cm$^2$, painted white, not to establish the visibility depth but to establish the colour of the sea [12, 13]: "*I prepared a square sheet of tinned iron, fourteen inches long, painted it white on one side, suspended it horizontally to a cord, and sunk it in a deep place, where the water under the boat, was blue without any mixture of green, watching the effect under the shade of an umbrella which was held over my head. At the depth of twenty five feet, it acquired a very sensible green tinge, and this color became more and more intense to the depth of forty feet when it was of a beautiful green, inclining to yellow; at sixty feet the color was the same, but of a darker shade, and the square Figure of the plate was no longer distinguishable; until at eighty feet, there was apparent only an uncertain glimmering of green which soon disappeared.*"



**dissemblables. A Offak, dans l'île Waigiou, par un temps calme et *couvert*, le 13 septembre, le disque disparut quand il fut descendu de 18 mètres (55 pieds). Le lendemain 14, le ciel étant *serein*, on ne cessa de voir le même disque qu'à la profondeur de 23 mètres (70 pieds).**

FIG. 3 Louis Isidore Duperrey (1786-1865). Text as noted, by the commander himself, in a chapter on marine observations published in Annales de chimie et physique (1825).



the island as we returned. Much is said of the clearness of these waters— certain subjects can be seen at a great depth say 6 or 7 fathoms—a white towel for instance tied to the line

FIG. 4 Notes in Jackson Kemper's diary (1834) during his visit to Green Bay showed a white towel used to determine the transparency of water. Transcription: "*Much is said of the clearness of these waters - certain subjects can be seen at a great depth say six or seven fathoms - a white towel for instance tied to the line*" (Reproduced from the archives of the Wisconsin Historical Society, USA).

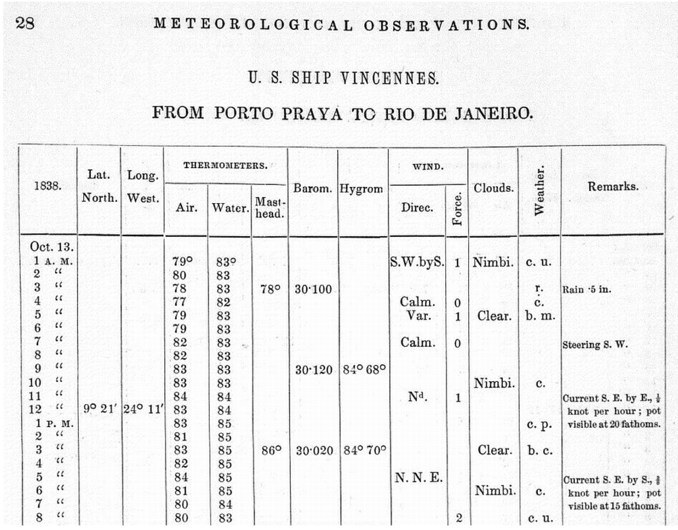
For the determination of the transparency, all kinds of equipment such as plates, tins, kitchen-gear, painted thermometers or copper balls ("diaphanometer", see [14]) were submerged into the water and lowered until they disappeared. Kemper around 1834 [15] used a white towel to measure the clearness of the water (see Figure 4).

The variety of objects used to measure transparency is also illustrated by the remarks of some captains. U.S. Navy Lt. Charles Wilkes (1798–1877) joining an US-squadron on its trip around the world (The Wilkes Expedition between 1838 and 1842) performed water transparency measurements like Navy Captain James Glynn (1800–1871) some years later [16], both using a simple white painted iron pot. During Wilkes trip from Funchal (Madeira) via Porto Praya (Cape Verde Islands) to Rio de Janeiro he observed "pot visibilities" (see Table 2) between 2 1/2 fathoms and 20 fathoms (4 1/2 m to 36 m) [17]: "*First we tried an iron pot, painted white, next we tried a sphere of hoops, covered with white cotton cloth. Then we tried a mere hope, covered with a canvas. At last we took a common white dinner plate. It was good enough.*"

Captain Auguste Bérard also used a porcelain dinner plate, mounted in a fish net, during the French Arago Expedition in 1845. Passing the South Pacific Wallis Island on July 16 he measured a "dinner plate" disappearance depth of 40 m [18].

Under command of Samuel Phillips Lee (1812–1897) the transparency of the sea was measured from the U.S. Surveying Brig "*Dolphin*" by means of lowering white painted foot square blocks [19].

As mentioned before, all kinds of attributes were used to establish the clarity of natural water. From a complete different field of science came Michael Faraday (1791–1867) who, in 1855, crossed the Thames River on a steamboat. He had subsequently done good service by calling public attention to what he then observed. Literally he stated [20, 21]: "*The appearance and the smell of the water forced themselves at once on my attention. The whole of the river was an opaque pale brown fluid. In order to test the degree of opacity, I tore up some white cards into pieces, moistened them so as to make them sink easily below the surface.*"



28 METEOROLOGICAL OBSERVATIONS.

U. S. SHIP VINCENNES.

FROM PORTO PRAYA TO RIO DE JANEIRO.

| 1838. | Lat. North. | Long. West. | THERMOMETERS. Air. | Water. | Mast-head. | Barom. | Hygrom | WIND. Direc. | Force. | Clouds. | Weather. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Oct. 13. | | | | | | | | | | | | |
| 1 A. M. | | | 79° | 83° | | | | S.W.byS. | 1 | Nimbi. | c. u. | |
| 2 " | | | 80 | 83 | | | | | | | | |
| 3 " | | | 78 | 83 | 78° | 30·100 | | | | | r. | Rain ·5 in. |
| 4 " | | | 77 | 82 | | | | Calm. | 0 | | c. | |
| 5 " | | | 79 | 83 | | | | Var. | 1 | Clear. | b. m. | |
| 6 " | | | 79 | 83 | | | | | | | | |
| 7 " | | | 82 | 83 | | | | Calm. | 0 | | | Steering S. W. |
| 8 " | | | 82 | 83 | | | | | | | | |
| 9 " | | | 83 | 83 | | 30·120 | 84° 68° | | | | | |
| 10 " | | | 83 | 83 | | | | | | Nimbi. | c. | |
| 11 " | | | 84 | 84 | | | | N^d. | 1 | | | Current S. E. by E., ½ |
| 12 " | 9° 21′ | 24° 11′ | 83 | 84 | | | | | | | | knot per hour; pot |
| 1 P. M. | | | 83 | 85 | | | | | | | c. p. | visible at 20 fathoms. |
| 2 " | | | 81 | 85 | | | | | | | | |
| 3 " | | | 83 | 85 | 86° | 30·020 | 84° 70° | | | Clear. | b. c. | |
| 4 " | | | 82 | 85 | | | | | | | | |
| 5 " | | | 84 | 85 | | | | N. N. E. | | | | Current S. E. by S., ⅜ |
| 6 " | | | 81 | 85 | | | | | | Nimbi. | c. | knot per hour; pot |
| 7 " | | | 80 | 84 | | | | | | | | visible at 15 fathoms. |
| 8 " | | | 80 | 83 | | | | | 2 | | c. u. | |

TABLE 2 Part of a meteorological table filled with data collected during the U.S. Exploring Expedition during the years 1838, 1839, 1840, 1841, 1842 under the command of Charles Wilkes (see under remarks on "pot visibility").

During his 1858 to 1860 investigations in the Gulf of Quarnero (Croatia), Josef Roman Lorenz, later known as Josef Roman Lorenz Ritter von Liburnau, measured the transparency of the sea by lowering a "batho-"thermometer[1] [22] with a white painted lid (see Figure 5) [23]. During later investigations, for instance in the Halstättersee (Lake in Austria), he used a white painted tin disc of 30 cm diameter [24]. The naming of the Secchi-disc was especially questioned by Josef Roman Lorenz von Liburnau at the end of the era who himself called the method "the disc system". Literally Lorenz writes in a chapter on limnology [24]: "*As substantially different methods are not commonly conceivable one always falls back to one and the same method to establish the boundaries of the visibility under water, I used it in 1858–1860, seven years before Secchi, during my investigations in the Quarnero, without considering it as a memorable invention. However, the procedure became commonly known as the "Secchi System"; I call it "Disc-System".*"[2]

In all mentioned publications thus far, including the one of Lorenz, it was never investigated nor explained why discs were used of an approximate 30 cm to 35 cm (1 feet). Perhaps

[1] Das Instrument ist bei den Untersuchungen des Verfassers im Quarnerischen Golfe zur Anwendung gekommen, wo es sich um Tiefen von nicht mehr als 60 Faden handelte, also möglichste Einfachheit und leichteste Handhabung verlangt wurden. Translation: *During the author's research in the Gulf of Quarnero, the instrument has been used, at depth not over sixty Fathoms, for its simplicity and the ease of handling.*

[2] Da eine wesentlich andere Methode nicht wohl denkbar ist und auf die selbejeder verfallen muss, der sich über die Grenzen der Sichtbarkeit unter Wasser informieren will, habe ich dieselbe als selbverständlich schon 1858–1860, sieben Jahre vor Secchi bei meinen Untersuchungen im Quarnero angewendet, ohne darin eine nennenswerte Erfindung zu erblicken. Es ist nun üblich geworden, dieses Verfahren System Secchi zu nennen; ich nenne es das Scheiben System.

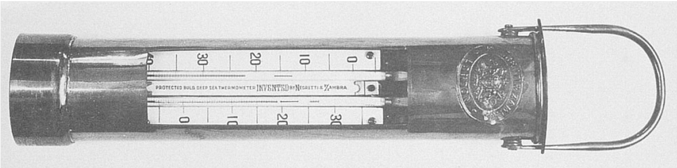


FIG. 5 The so-called "batho-"thermometer with a white painted lid (right). The instrument was used in vertical position in the Adriatic to establish the sea's visibility, next to the temperature.

FIG. 6 Padre Pietro Angelo Secchi (1818-1878)

the porcelain dinner plates used on several occasions were close to this diameter.

## 3 THE WHITE DISC AS STANDARD

Two years after Lorenz's 1863 publication on physical properties of the Quarner Gulf, including his transparency observations, an article on the same topic appeared in a weekly magazine of the French Academy of Science. Alessandro Cialdi and Angelo Secchi (see Figure 6) performed transparency measurements in the Tyrrhenean Sea in front of Civitavecchia near Rome. In a barely three pages long article, observations onboard the papal corvette "*Immacolata Concezione*" and methods to establish the water transparency were described [25] with a brief description of the size, material and colour of the employed discs.

As lots of scientists and captains dealt with the transparency phenomenon of the sea far before Secchi and looking at the published material before and around the time of Cialdi and Secchi, we can still not make it plausible why the method at the end of the nineteenth century became known as the Secchi disc method.

However, looking at forgotten chapters published in the Italian scientific Journal *Il Nuovo Cimento* in 1865 [26] and in Cialdi's book *Sul Ondoso del Mare* [27] of 1866, it definitely clarified the naming of the method. In the two identical thirty-two paged chapters all aspects of transparency disc measurements are described. The colour of the disc, its diameter and the height of the sun are described in relation to its disappearance depth. Furthermore the positions, such as the bow of the ship, from which measurements were performed, were taken into account. In Table 3 an example of the height of the sun and the disappearance depths per disc diameter (*grande* = large, *piccolo* = small) are shown. At this point it goes too far to mention all of Secchi's results. But by reading Secchi's original work it became clear why the method finally becomes known as the Secchi-disc method. (Requests for a copy of Secchi's publication in the scientific Journal *Il Nuovo Cimento* can be made to marcel.wernand@nioz.nl).

| ALTEZZA DI SOLE | | PROFONDITA' DI VISIBILITA' disco grande | PROFONDITA' DI VISIBILITA' disco piccolo |
|---|---|---|---|
| 25°.48' | | 24m.5 | |
| | 30°. 4' | | 22m.7 |
| 45. 24 | | 33. 9 | |
| | 41. 53 | | 27. 3 |
| 59. 52 | | 36. 7 | |
| | 59. 39 | | 32. 2 |

TABLE 3 In an experiment on 21 April 1865, Secchi tabulated the results of the disappearance depths of a small and a large disc used under different sun heights.

## 4 POSTSCRIPT

In 1984 five observers, sailing in the eastern Mediterranean, viewed a marine standard, 40 cm, white Secchi disc through a 20 cm hole in the "hero platform" (the bucket in which scientists stand while deploying instruments over the side of a research vessel) and determined a depth of 53 m [28]. However, two years later this record was broken by Gieskes and three other observers [29] in the Antarctic and the Secchi depth was determined at a depth of 79.5 m. Until the time of writing a world record with French oceanographers following with a Secchi depth of 74 m observed near Easter Island [30]. A world record Secchi depth has been claimed but we have to bear in mind the observation mentioned at the beginning of this contribution, which is still a robust water visibility record that stands for over 3 centuries: a bottom seen at 146 m depth by Captain John Wood near Nova Zembla in June 1676. Theoretically, in the purest natural waters, according to calculations of René Dirks [31] the maximum Secchi-disc visibility is between 150 m and 170 m.

The late twentieth century has brought us a variety of advanced optical instruments to determine the transparency of sea water electronically. However, the author recommends a reintroduction of the Secchi disc to expand the historical Secchi depth database to facilitate climate change research. One option is to mount a Secchi disc on an instrumental- or CTD frame. Historic Secchi depth data can be retrieved from oceanographic and meteorological databases archived by the United States National Oceanographic Data Centre (NOAA-NODC). The NODC global oceanographic dataset contains over 400000 Secchi depth observations and belongs to the oldest instrumental datasets quantifying the world seas for over more than a century.

A detailed analysis of the physical and physiological aspects of the Secchi disc can be found in Preisendorfer [32], Graham [33] and Tyler [34] and W. Hou *et al.* [35]. The basic part of this contribution originates from a paper presented at Ocean Optics 2008 by Wernand which was extended in various ways including the addition of historic illustrations.

## ACKNOWLEDGEMENTS

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