Measurement and Analysis of offshore fog occurrences

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1. Abstract

The occurrence of fog presents a hazard to marine operations in many areas. While this hazard is well known to experienced mariners, it is important to describe and document the nature and extent of their occurrence. The used sensor is a forward-scatter sensor. Those sensors have a projector that transmits a beam of light. The amount of light scattered forward into a receiver is measured. This sensor is competitive in accuracy, reliability, and cost with the other types of sensors. The Fog occurrences were analysed to gather information about: the duration, the velocity of the visibility change and the probability of short versus long fog events.

Fog events were detected when the visibility reaches values below the limit of 1000m. The fog events show in most cases a rapid start and end. A slow beginning of fog events was rare.

2. Introduction

In the coming years a lot of offshore wind farms will be built. From the safety point of view a wind farm has to be located where shipping and/or flight densities are low. However, for the best wind resources or circumstances (waves/ground) of the offshore wind farm other locations might be used. An important safety point is the visual determination of those wind farms in the case of low visibility caused by haze, mist or fog.

3. Fog

Fog consists of tiny water droplets (about 10µm to 40µm in diameter), floating in the air and thereby causing the extremely strong decline of visibility. If someone would like to improve the sight or the visibility in the fog or haze by turning on headlights, he must take the direct glare through the backscattering of light in the fog into account.

4. Scattering

The scattering from molecules and very tiny particles (< 1 /10 wavelength) is predominantly Rayleigh scattering. For particle sizes larger than a wavelength, Mie scattering predominates. This scattering produces a pattern like an antenna lobe, with a sharper and more intense forward lobe for larger particles. Mie scattering is not strongly wavelength dependent and produces the almost white glare around the sun when a lot of particulate material is present in the air. It also gives us the white light from mist and fog. [1]

The scattering of the light by fog droplets is not uniform in all directions (Mie-Scattering). The largest portion of the light is scattered forward, a smaller part back, but this just causes a strong direct glare. The phenomenon is well known, if you turn on the headlights when driving in fog. Often, the backscattered light is so bright that you must immediately slow down. Even when flying against the low sun, it comes through the forward scattering to extreme decline of visibility.

5. Devices and principles

There are different measuring principles:

- transmission (extinction)
- scattering (backscatter and forward scatter)

for the determination of meteorological optical range (mor).

“The meteorological optical range is defined as the length of the path in the atmosphere that is required to attenuate by 95% the luminous flux in a collimated beam from a light source at a colour temperature of 2700 K.” [2]

6. Transmission

A device measuring the extinction coefficient of the atmosphere using transmitted light is called transmissometer. It operates by sending a collimated beam of light through the atmosphere. A narrow field of view receiver at a constant measurement distance determines how much light is arriving at the detector. By using this Information the extinction coefficient is derived.

Figure 2 shows the placement of a light source and detector. As photons pass through particles and gases along the baseline, they are either scattered out of the light path or they are absorbed. A photodetector placed as indicated measures only those photons that are transmitted the length of the light path. This instrument is sensitive to both scattering and absorption; it can be calibrated to measure the extinction coefficient. Those devices are used as measuring devices and calibration standards. Transmissometers are quite large because they need a long baseline (15m up to 100m) and thy need a very precise alignment. These measuring devices are very sensitive to contaminations.

7. Scattering devices

Scatterometers measure the amount of light scattered by aerosols in an optical volume, observed within a small angle. The extinction coefficient can be derived.

Figure 3 shows a forward scattering device. The extinction coefficient is linear with the relative amount of measured light scattered inside an optical volume. Scatterometers use the same light chopping techniques as Transmissometers. A number of modern Scatterometers are also provided with the feature to measure contamination of the optics and to correct and warn for it.

8. Back scatter

Figure 4 shows the design in principle of a backscatter device.

Several researchers have tried to find a relationship between visibility and the coefficient of back scatter, but it is generally accepted that that correlation is not satisfactory. [3]

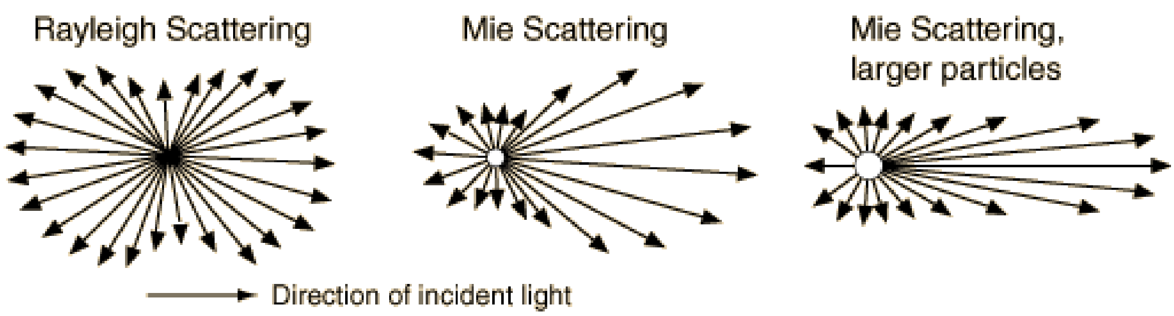

Fig. 1: Different scattering [1]

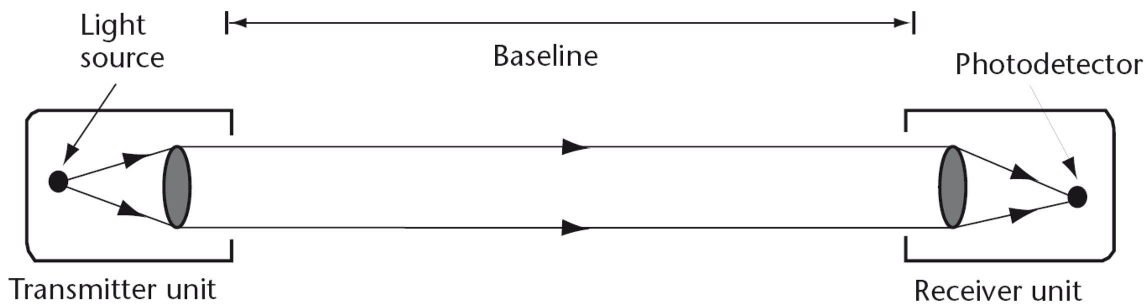

Fig. 2: Transmissometer [3]

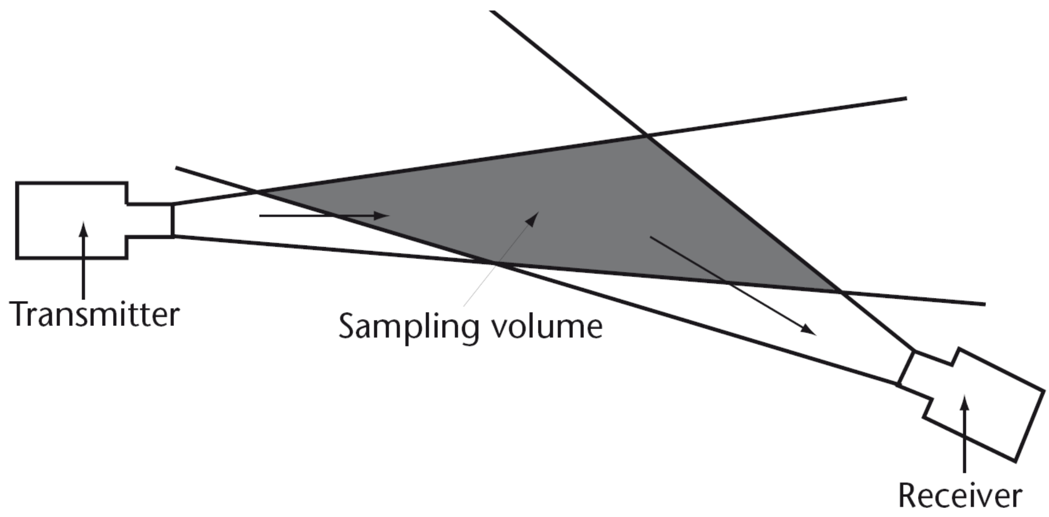

Fig 3: Forward scattering device [3]

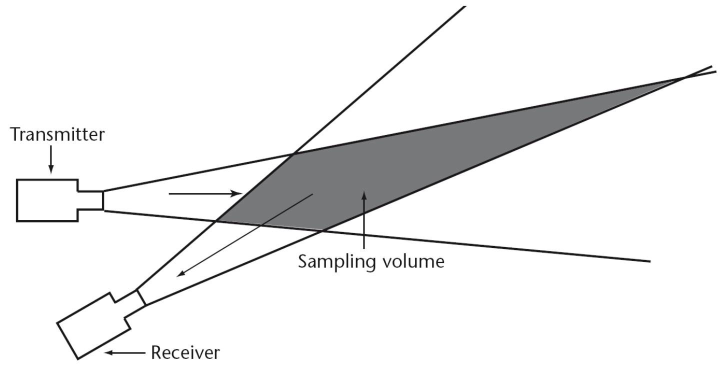

Fig 4: Backscatter device [3]

9. Forward scatter

The forward-scatter sensor has a projector that transmits a beam of light. The amount of light scattered forward into a receiver is measured. This sensor is competitive in accuracy, reliability, and cost with the other types of sensors. Its compact size and light weight make it relatively easy to mount and it is fast becoming the predominant type of fog sensor. [4]

10. Location

Measuring instruments should be located in positions which ensure that the measurements are representative for the intended purpose. The volume of air in which the extinction coefficient or scatter coefficient is measured should normally be at the eye level of an observer, about 1.5 m above the ground. [3]

Offshore conditions will lead to other measuring heights. The waves and the spray of the waves will harm the instruments. To avoid these circumstances the measuring devices should be located away of the splash zones. Heights of around 20 m to 30 m above the sea level will be sufficient for many locations.

For all instruments the sun has to be kept out of the optical field at any time of the day. This limitation can be a problem when mounting the devices on the nacelle of a windturbine.

11. Maintenance

Regular checks and calibration in accordance with the manufacturer's recommendations should ensure optimum performance. Calibration in very good visibility (over 10 km to 15 km) should be carried out regularly. [3]

12. Research on Fog occurrence

The number of articles including the word "fog" in Journals of American Meteorological Society alone was found to be over 4700, indicating that there is substantial interest in this subject. In spite of this extensive body of work, our ability to accurately forecast/nowcast fog remains limited due to our incomplete understanding of the fog processes over various time and space scales. Fog processes involve droplet microphysics, aerosol chemistry, radiation, turbulence, large/small-scale dynamics, and surface conditions (e.g., partaining to the presence of ice, snow, liquid, plants, and various types of soil). Another relatively well-studied fog type is associated with the advection of a moist airmass with contrasting temperature properties with respect to the underlying surface and is therefore referred to as advection fog. Sea fog typically occurs as a result of warm marine air advection over a region affected by a cold ocean current, and thus, it is common at sea in locations where boundaries with cold ocean currents can be found. [5]

13. Approach

The occurrence of fog presents a hazard to marine operations in many areas. While this hazard is well known to experienced mariners, it is important to describe and document the nature and extent of their occurrence. Figure 5 and Figure 6 show a fog occurrence with a sharp zoning.

Fig. 5: Fog event

Fig. 6: Fog event

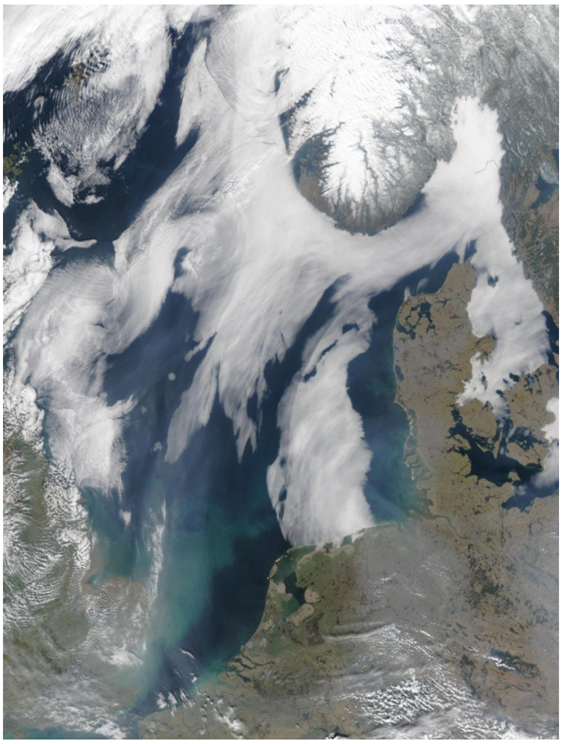

Fig. 7: Satellite image of fog or stratus event [6]

Figure 7 shows a part of the North Sea, with a big cloud or fog event. By using satellite pictures it is not possible to determine the height and the thickness of the clouds. In order to avoid this ambiguity a measurement in the height of interest is essential.

For all instruments the sun has to be kept out of the optical field at any time of the day. This limitation can be a problem when mounting the devices on the nacelle of a wind turbine.

Vaisala present weather sensors PWD 12 were used for these measurements. Figure 8 and Figure 9 show the sensor and the optical arrangement.

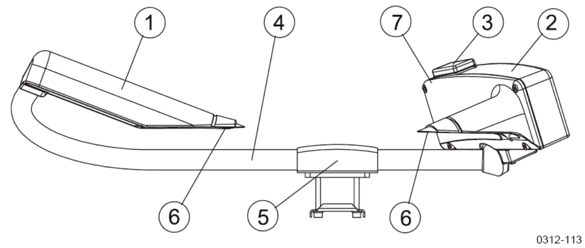

Fig. 8: Used Present Weather sensor [7]

The following numbers refer to Figure 8 above.

1 = Transmitter

2 = Controller/Receiver

3 = RAINCAP® Rain Sensor

4 = Pt100 temperature sensor in the tube

5 = Mounting clamp

6 = Hood heaters (optional)

7 = Place for Luminance Sensor

[7]

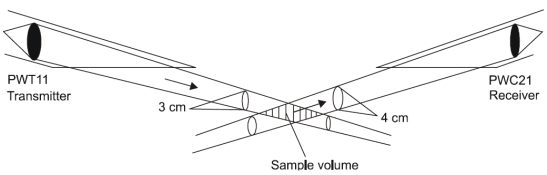

Fig. 9: Optical Arrangement [7]

The used sensor is a forward-scatter sensor. Those sensors have a projector that transmits a beam of light. The amount of light scattered forward into a receiver is measured. This sensor is competitive in accuracy, reliability, and cost with the other types of sensors. Its compact size and light weight make it relatively easy to mount and it is fast becoming the predominant type of fog sensor. [8]

Fig. 10: Metmast Amrumbank West

The measured Data was collected by metmasts in the North Sea and by PWD-Sensors mounted on the nacelle of offshore wind turbines.

The longterm data was taken form the data delivered by the metmast Amrumbank West (Fig. 10).

The following figures show different fog events.

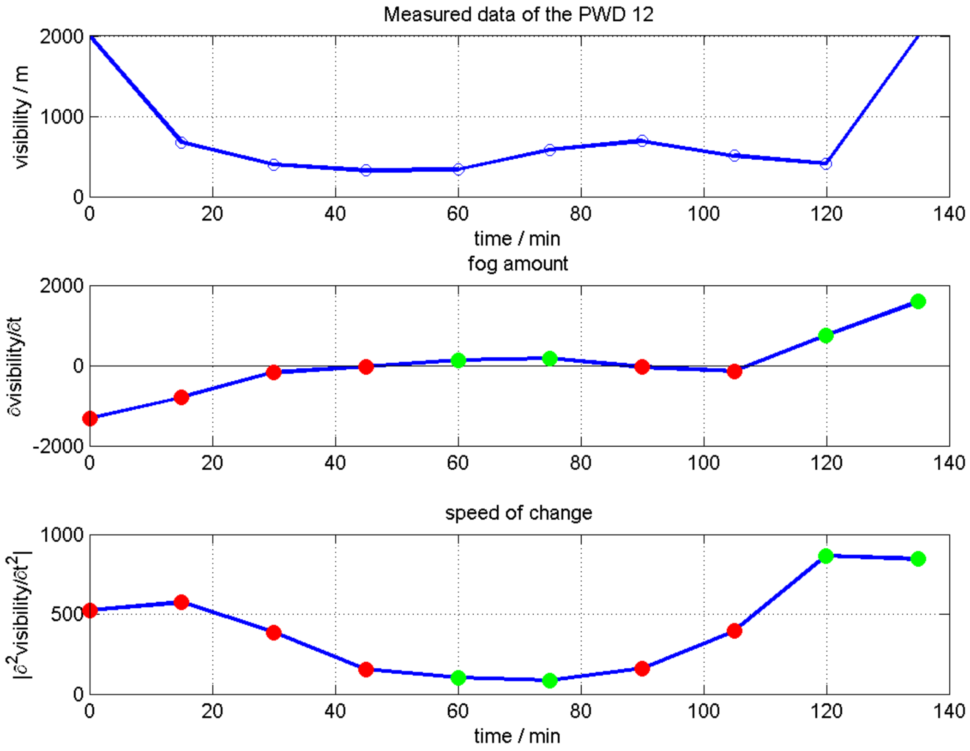

Fig. 11: Fog event of around 110 minutes

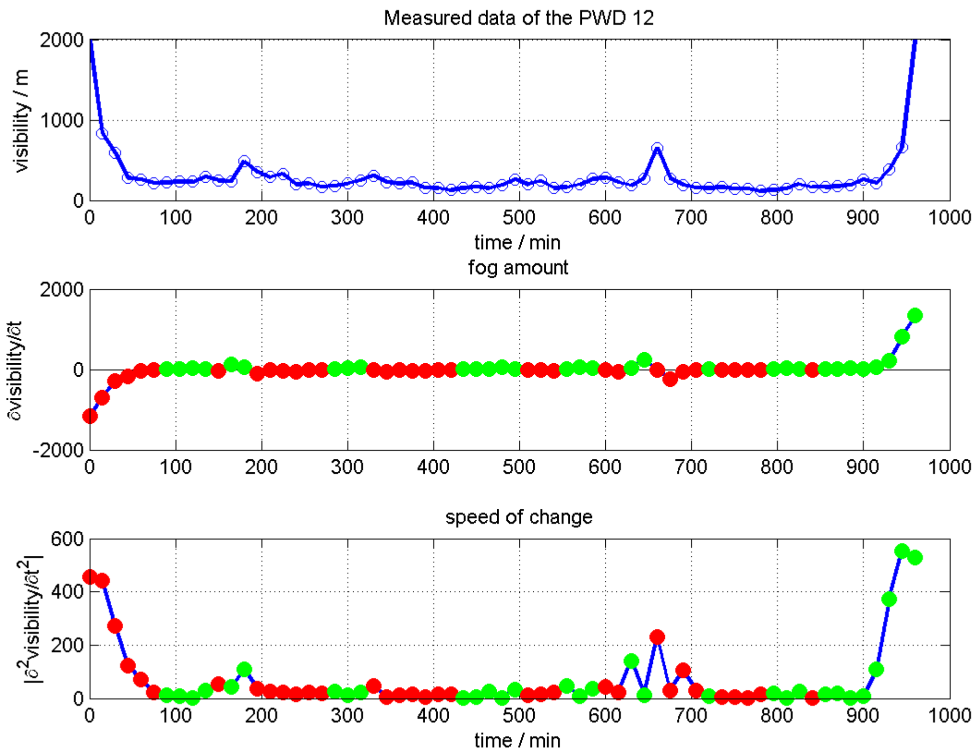

Fig. 12: Long Fog event

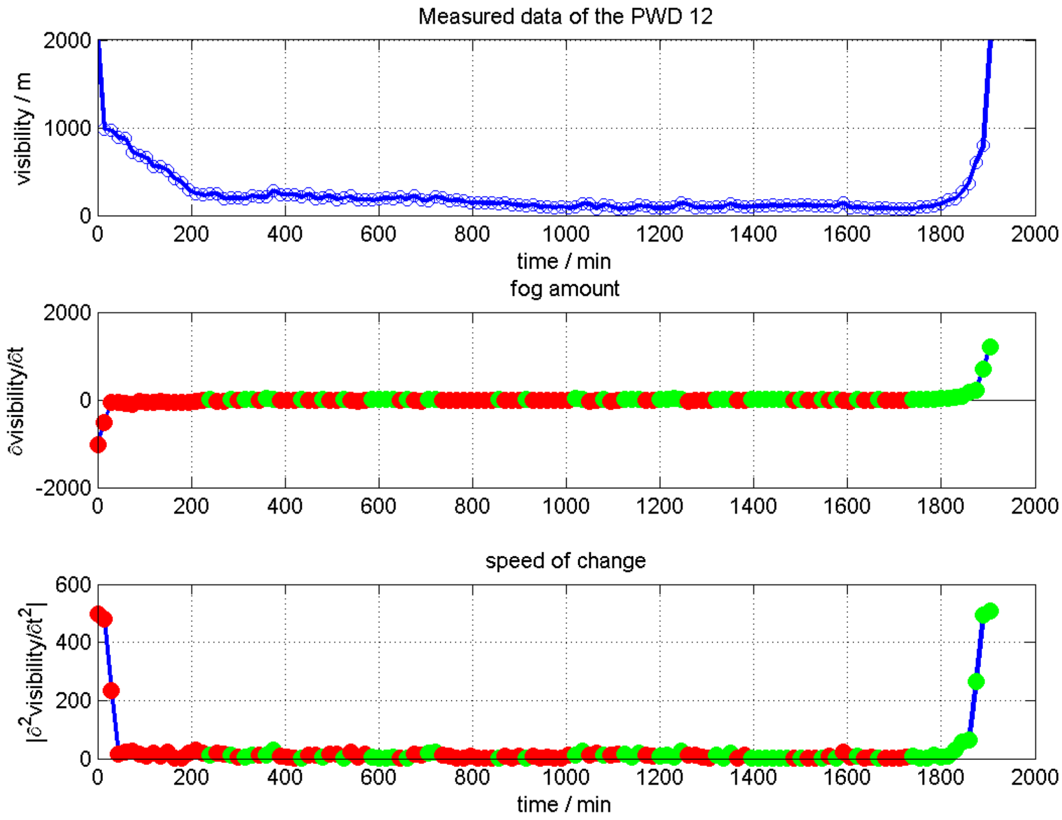

Fig. 13: Long Fog event

14. Fog events

The total economic loss associated with the impact of fog on aviation, marine and land transportation can be comparable to those of tornadoes or, in some cases, winter storms. [9]

For all measured values it is important to know that measurements in a small volume of the atmosphere normally fluctuate rapidly and irregularly. Several comparisons like [10] show that forward scatter measuring devices, if calibrated properly, will meet the accuracy requirements, especially for values of MOR above 1000 m. In offshore conditions those devices have to be mounted in a way to prevent contamination with salty water or spray.

Fog events were detected when the visibility reaches values below the limit of 1000 m. The fog events show in most cases a rapid start and end. A slow beginning of fog events was rare. The figures 11 to 13 show typical fog events. The event shown in figure 11 is an event with lasted for nearly two hours. Figure 12 shows a rather long fog event with duration of over 900 minutes. The second part of each pictures show the velocity of the visibility change (first derivation regarding time), the lowest diagram of those figures show the second derivation of the visibility. In the beginning the speed of the visibility change goes down to nearly zero. When the fog is present the speed of change varies only between narrow limits. This is independent of the duration time. Figure 13 shows a rather long fog event with duration of over 30 hours. Those events occur not very often, but the behaviour is similar to the short fog occurrences. The fog starts abrupt and end abrupt. The changes in visibility are only minor during the event.

The histogram in Figure 14 shows short fog events occur significantly more frequent than long fog events. Very short events occur frequent. Fog events with a duration time of over 8 hours are rather seldom.

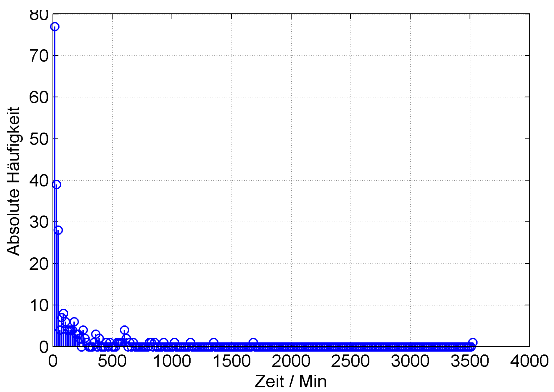

Fig. 14: Histogramm

15. References

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