Instruments and Observing Methods,
Report 57. pp. 97-101. World
Meterorological Organisation 1994

NEW SHIP RAIN GAGE

L. Hasse, M. Großklaus and K. Uhlig
Institut für Meereskunde, Kiel, Germany

Introduction

Measurements of precipitation at sea are an important part of the WCRP and GAW. Life on earth crucially despends on water supply. The hydrological cycle is intimately linked with almost all aspects of climatic change. Precipitation at sea forms by far the strongest branch of the hydrological cycle. Yet, undisturbed precipitation measurements at sea, except from a few stations at small islands, are practically not existent. We hope that in future numerical weather forecast models and satellite remote sensing methods will provide improved precipitation estimates for the world oceans. However, precipitation estimates from weather forecast models and satellite remote sensing algorithms urgently need ground truth at sea, as do ground based remote sensing methods, e.g. seaward looking radars.

The present note deals with a specialised mechanical ship rain gage that was developed at Institut für Meereskunde Kiel in order to overcome the difficulties for rain measurements at sea from moving ships. Our contribution today is an update of earlier reports that we have delivered at other WMO meetings. We believe that now, after a number of years of tests and improvements and after two years of routine use, the ship rain gage reliably can be used at other ships. To my opinion, the time has come to introduce ship rain gages at voluntary observing ships.

Conventional rain collecting instruments fail when used at buoys or ships. The problem stems from the rather high flow velocities around rain gages at ships, that may result from addition of wind and ship velocities. This yields to two sources of biases:

(i) The flow around the ships superstructure may induce spurios vertical velocities and enhanced or reduced speeds at the location of the equipment, leading to under- or overcatch.

(ii) The flow around the raingage for most conventional types of raingages tends to carry the rain above the orifice of the gage, leading to a wind speed dependent undercatch.

Of these two sources of error the first one is easier to deal with. The effect of flow distortion from the ships superstructure can be alleviated somewhat by suitable siting of the instrument, say above the flying bridge, where the flow might be expected to be nearly horizontal (Austin and Geotis, 1980). Also, the measurement technique could make the instrument less susceptible to high speeds and to local up-/or downdrafts.

Basic principle

Our ship rain gage is designed to enable rain fall measurements from moving ship where relative wind speeds of 10 to 20 m/sec are not uncommon. The high relative flow velocities may carry the rain almost horizontally over the ship. We have therefore fitted the instrument with a lateral collecting surface. By measuring the amount of water collected at the side, a correction for the wind speed effect is possible. It is evident that the local relative wind speed at the site of the instrument needs to be measured simultaneously.

The lateral collecting surface measures liquid water content in the volume of air that is formed by the cross-section of the gage and the local relative windspeed. From the liquid water content of the air, the rainfall rate can be estimated by assuming a raindrop size distribuion. The horizontal orifice measures rainfall like any landbased conventional raingage. We have taken care to reduce the wind induced errors by an improved aerodynamic design. From the informations of the two collecting surfaces, considering local flow velocity, the rain fall rate can be determined.

Technical realisation

In our design, the horizontal orifice of a conventional raingage has been supplemented by a cylindrical lateral collecting surface (figure 1) . The water amount from both surfaces is collected separately, and measured by forming and counting drops of calibrated size. The aerodynamic shape of the instrument was designed to reduce the undercatch resulting from flow distortion by the gage itself. Specially, the upper part, that forms the horizontal orifice, roughly corresponds to the champagne bowl design recommended by Folland (1988) but has a more slender shape and less wind resistance.

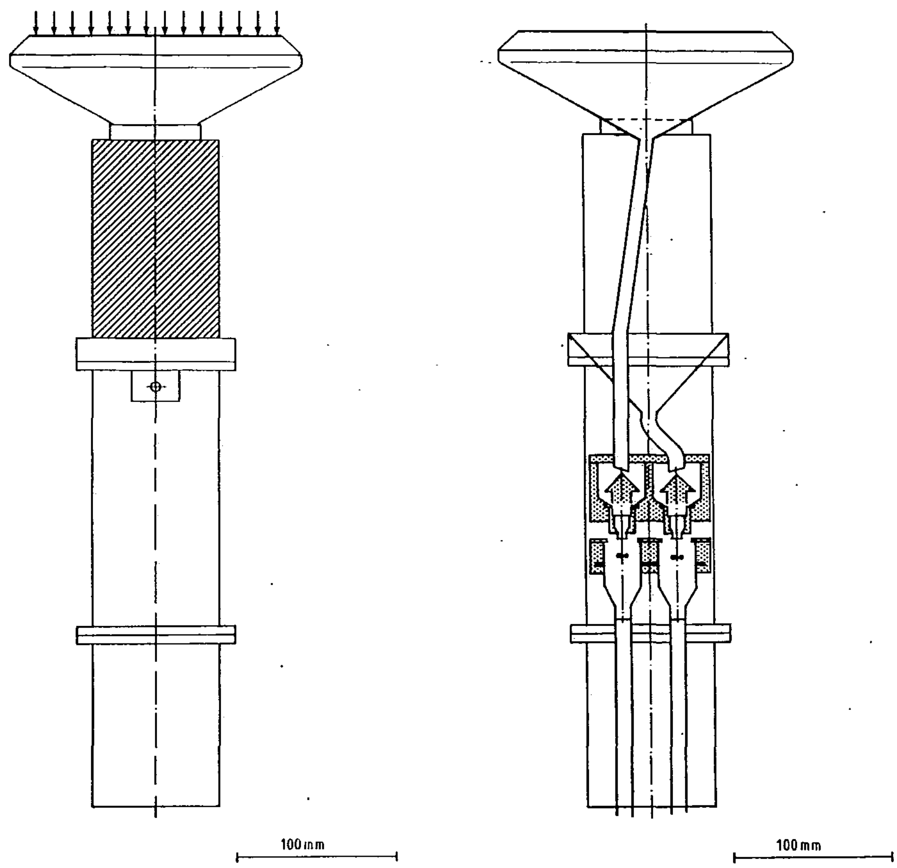

Figure 1 Side view and vertical cross-section of the ship rain gage
Rain is collected at the horizontal orifice (arrows) and at the lateral collector (shaded). There are 5 vertical T-bars at the circumference of the lateral collector that hinder rain water to wander around the cylinder and be blown off in lee (not shown in the diagram). Horizontal sampling area is 200 cm^2, and lateral sampling cross-section 106.6 cm^2. Total length is 48.5 cm and weight 4.0 kg

Calibration

The calibration of the ship rain gage depends on the flow around the instrument. Even with the improved aerodynamic shape, some wind influence on the catch with the horizontal collector is expected (Sevruk, 1989), and an empirical calibration is necessary. The catch of the liquid water content at the side also depends on the aerodynamics of flow around the cylinder. Its effective cross-sectional area needs not equal the geometric cross-section. Hence, we calibrate the ship raingage in the field in natural rain. Calibration is obtained in situ by simultaneous measurements with an optical disdrometer by steaming the ship in the wind. An example of such measurements is given in figure 2. The correlation appears to be rather good. There is some unevitable scatter due to different sampling characteristics: According to our experience, the scatter is mainly due to the sampling variability of the optical disdrometer: Its active cross-section is by a factor of four smaller than that of the ship rain gage. When we assume that the unexplained error variance is distributed 4:1 between disdrometer and ship raingage, we arrive at an sampling error of roughly 7% for short term averages (8 minutes). Hourly or daily totals will be considerably more stable. The in field calibration also allowed to check the performance of the upper and sideward collection separately. It was found that at low wind speeds the measurements by the upper orifice are more accurate, while at higher relative wind speeds the lateral collection performs better. Hence, we use one or the other collecting surface according to wind speed with a linear transition between 9 m/s and 11 m/s. It may be mentioned that the drop forming devices are rather linear and agree with each other up to a rain intensity of about 60 mm/h. For higher rain rates calibration is possible, but behaviour of individual drop formers differs.

Results

Comparisons of the ship rain gage have been conducted both at sea against ship borne optical disdrometers and at land against standard meteorological rain gages. The intercomparison at land has been made at the test site of the Deutscher Wetterdienst at Harzgerode. There the ship raingage was mounted such that the horizontal orifice was at 1 m height above the ground. The same height was used with the standard Hellmann type recording rain gage of the weather service. Additionally, a Hellmann rain gage in a pit, with its orifice level with the surrounding ground, was used.

Hellmann rain gage	**ship rain gage**	**pit rain gage**
1 m	1 m	ground level
459 mm	494 mm	498 mm
92.2 %	99.2 %	100 %

Table 1: Comparison of rain gages at the precipitation test site of Deutscher Wetterdienst Harzgerode, January through November 1993. The intercomparison is based on daily averages, cases with solid precipitation are excluded. Since the mean wind speeds measured at 1 m height rarely exceeded 5 m/s, only the measurements from the upper, horizontal orifice are considered.

Our design of the upper part of the instrument is very similar to the shape of a precipitation gage, that independently has been developed by Wiesinger (1993) for alpine use. Hence, our results are perhaps somewhat more gerneral than expected from the title of this lecture. With regard to the deployment of the gage at a ship it is worth noting that the measurement of the liquid water content at the side is independent of local up- or downdrafts. The catch by the horizontal orifice can be influenced by local up-/or downdrafts, depending on the drop-size distribution. This requires to place the instrument above the superstructure of the ship in order to minimize influence of local ship induced velocities. In order to deal with ship roll motions in a seastate, the instrument is suspended to swing freely around an axis parallel to the ship's long axis.

The instrument output provides counts of calibrated drops from the top and from the side. Typically, these are recorded together with the counts of a cup anemometer (and auxiliary data like date, time, position of ship) on a PC. Basic recording time unit is 2 minutes. For this time, rainfall rates are calculated for the top and the side separately and a corrected rain fall rate is obtained as a wind speed dependent weighted average.

Optical disdrometer

For calibration of the ship raingage we use optical disdrometers that have been built at our laboratory. The principle of operation is light extinction. Each drop passing through the active volume results in a reduction of light proportional to its cross-sectional area. Minimal detectable size of droplets is 0.32 mm. Each drop is measured separately and recorded with a resolution of 0.05 mm diameter to form a droplet size spectrum. The rain rate is determined from the droplet spectra by assuming terminal fall velocity of the drops according to their size. Our optical disdrometer uses a cylindric active volume, that is hold perpendicular to the local flow direction by aid of a wind vane. The cylindrical form makes the measurement independent of the incidence angle of the rain drops. Hence, local up- and downdrafts do not influence the measurements. The sensitivity of the optical volume can be calibrated quite accurately, hence the disdrometer can be used to calibrate the ship rain gage under natural conditions.

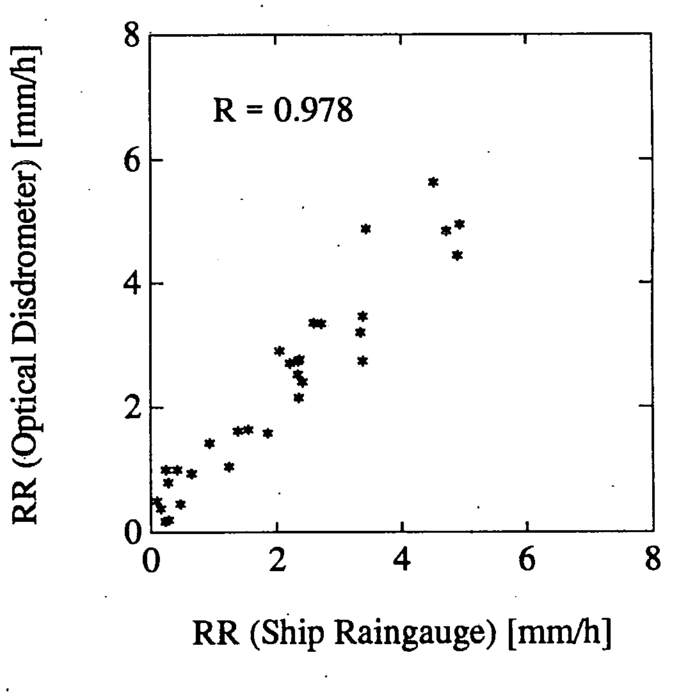

Figure 2: Calibration of ship rain gage against optical disdrometer from a cruise with R.V. ALKOR.
Time interval is 8 minutes. The scatter is mainly due to sampling characteristics of the optical disdrometer and reduces with longer averaging times.

It is anticipated that under windy conditions the standing Hellmann will experience some undercatch as a result of flow distortion, and that the measurements in the pit can be used as a reference. The results of the intercomparison of the earlier version of the ship raingage were given in Hasse et al (1993), they showed a surprisingly good agreement of our instrument with the pit raingage. The intercomparisons obtained during 1993 at Harzgerode are given in table 1. Unfortunately, situations of higher wind speeds with rain are rare, even at the exposed site of Harzgerode (in the Harz mountains, station height about 440 m). It shows that the ship rain gage compares well with the pit measured rain amount, better than the standard "Hellmann" does. Because of the moderate wind speeds, the comparison pertains to the upper, horizontal collector only.

Conclusion

We have shown the feasibility to measure rain at moving ship with a specialised ship rain gage. Calibration is obtained by use of optical disdrometer in natural rain. An intercomparison at land showed improved performance of the ship rain gage compared to standard rain gages, due to improved aerodynamic design.

Our ship rain gage has now successfully operated at R.V. METEOR for two years. We feel assured that we can recommend this ship rain gage to WMO for introduction to operational use at ships.

Acknowledgement

We thank the Deutsche Forschungsgemeinschaft for funding the development of the ship rain gage and the optical disdrometer as a contribution to WOCE. The Deutscher Wetterdienst kindly hosted our ship rain gage at its site in Harzgerode and provided the intercomparison data. The work of station manager Rönsch is appreciated. Also, we thank the personnel of the Deutscher Wetterdienst at R.V. METEOR who care for the operation of the ship rain gage.

References

Folland, C.K., 1988: Numerical models of the raingage exposure problem, field experiments and an improved collector design. Q.J.R.Meteorol. Soc. 114, pp 1485 - 1516.

Hasse, L., Großklaus, M., Isemer H.-J. and K. Uhlig, 1992: New instrumentation for measurement of precipitation at sea. In: Instruments and observing methods, Report No. 49, Geneva. WMO-TD - No. 462, pp 195 - 198.

Hasse, L., Großklaus, M. and K. Uhlig, 1993: Measurement of precipitation at sea. In: B. Sevruk and M. Lapin (eds.): Precipitation measurement and quality control. Slovak Hydromet. Inst., Bratislava, and ETH, Zürich, pp 36-41.

Sevruk, B., 1989: Precipitation measurement. WMO/LAHS/ETH Workshop on precipitation measurement, St. Moritz, Dec. 1989. ETH Zürich, pp 584.

Wiesinger, T., 1993: Improved design of precipitation gages based on aerodynamic principles. In: B. Sevruk and M. Lapin (eds.): Precipitation measurement and quality control. Slovak Hydromet. Inst., Bratislava, and ETH, Zürich, pp 143 - 147.