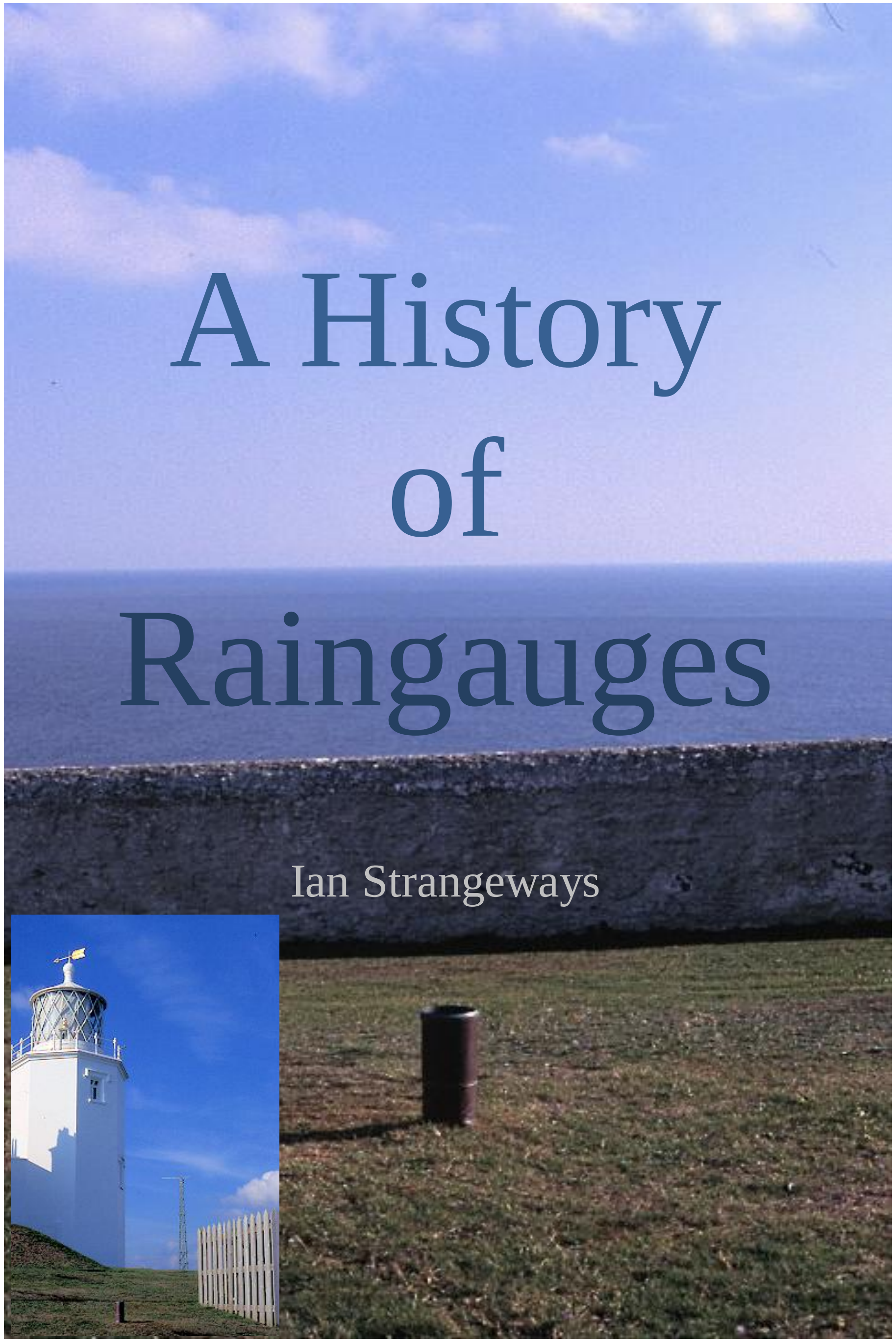
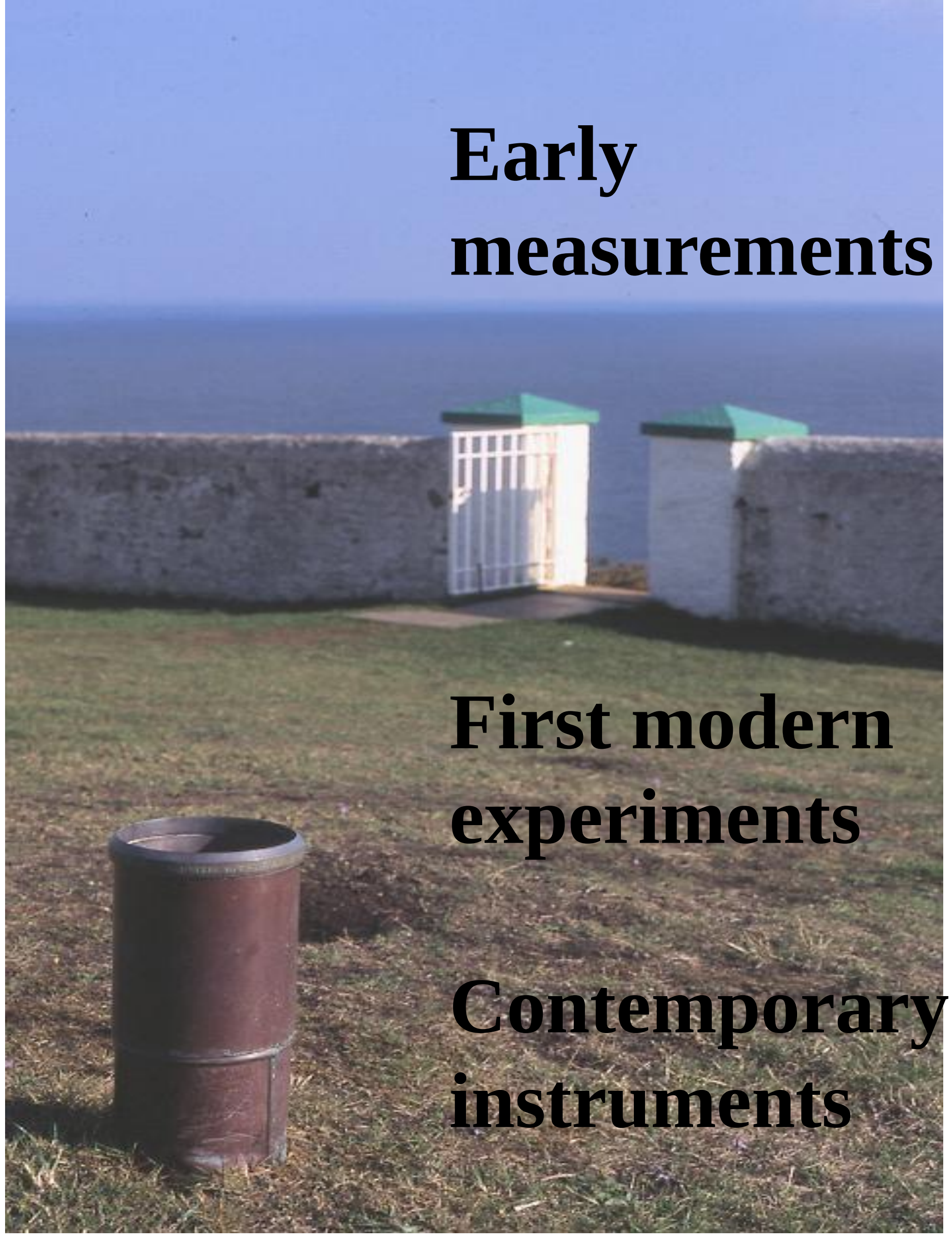
A History of Raingauges

Ian Strangeways




Early
measurements
First modern
experiments
Contemporary
instruments

In *Arthashastra*

(A treatise on state craft, economics, military matters and agriculture)

by Kautilya in fourth century BC India

In the section on agriculture it is reported that:

‘A bowl, as wide as an Aratni (18 inches), shall be set up as a raingauge.

According as the rainfall is more or less, the superintendent shall sow the seeds which require more or less water.’

In *The Mishnah*

(a written transcript of Jewish oral tradition)

Jewish life in Palestine is recorded from the second century BC to the second century AD.

In it is reported that the rainfall total for a year is 540 mm.

It is not clear, however, if this is just one year or the average of many

Rainfall today in the biblical lands varies from 600 mm by the coast to 150 inland by the Jordan River

A met site in the West Bank near Nablus and Tulkarm

View from the road between Jerusalem and Ramallah towards the Jordan River

In China, around 1247, rainfall measurements were described in a mathematical treatise *Shu shu jiuzhang* **'**Writings on Reckoning' by Qin Jiushao.

He describes how raingauges were installed at provincial and district capitals as well as bamboo snow gauges in mountain passes.

Qin Jiushao also discusses how point measurements were converted to areal averages.

This was very advanced for the time. Nothing equivalent was yet happening in the 'West'

Korea 1440

The Chinese gauges probably drifted into Korea.

This is a reproduction of the Korean raingauge at the Science Museum in London.

These gauges were operated from the 15th century right up until the early 20th century

1639

Castelli, a student of Galileo, made a one-off measurement of rainfall by Lake Trasimeno in Central Italy.

He partly filled a glass cylinder with water, marked the depth and exposed it to the rain for an hour. He then measured the increase in depth.

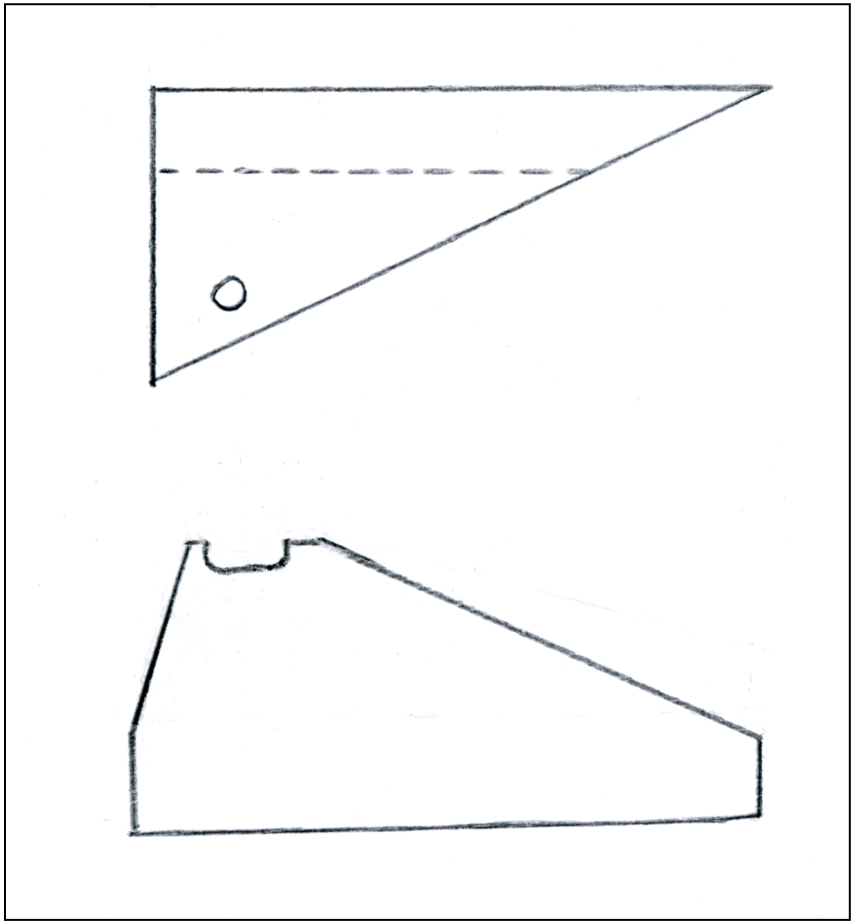
He wrote to Galileo about it, but he did not make regular measurements.

1660

Sir Christopher Wren
and
Robert Hooke

made a one-sided tipping bucket raingauge, as part of an automatic weather station that recorded its measurements on punch paper strip.

It was to be 400 years before such sophisticated instruments were repeated



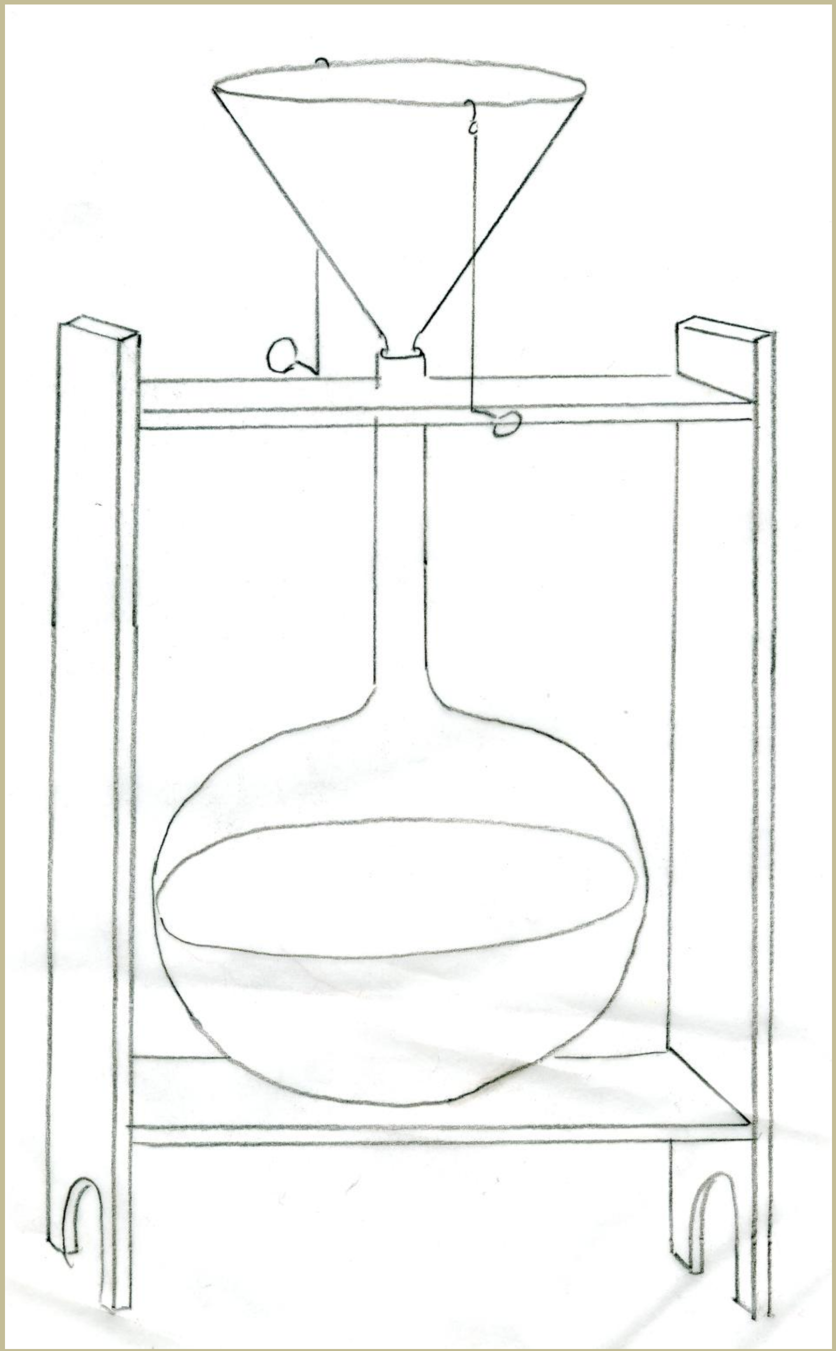
My sketch of how it appears to have been

Robert Hooke's manual gauge

was a bottle holding 9 litres of water with a glass funnel of 29 cm diameter.

Operated throughout 1695 at Gresham College, London, over the year collecting 737 mm.

But so far none of these gauges were operated for extended periods.



This is my redrawing from the original

Richard Towneley

Towneley made the first regular measurements of rainfall from January 1677 in the north of England and published monthly rainfall totals for 15 years.

His gauge was 30 cm in diameter, exposed on the roof of his house, connected by a lead pipe into house.

He described the measurements to the Royal Society "*to show how little trouble there is to this task; which therefore I hope some of your ingenious friends may be persuaded to undertake*".

But only William Derham took-up challenge.

Together they published rainfall measurements for Towneley and Upminster for 1697 to 1704.

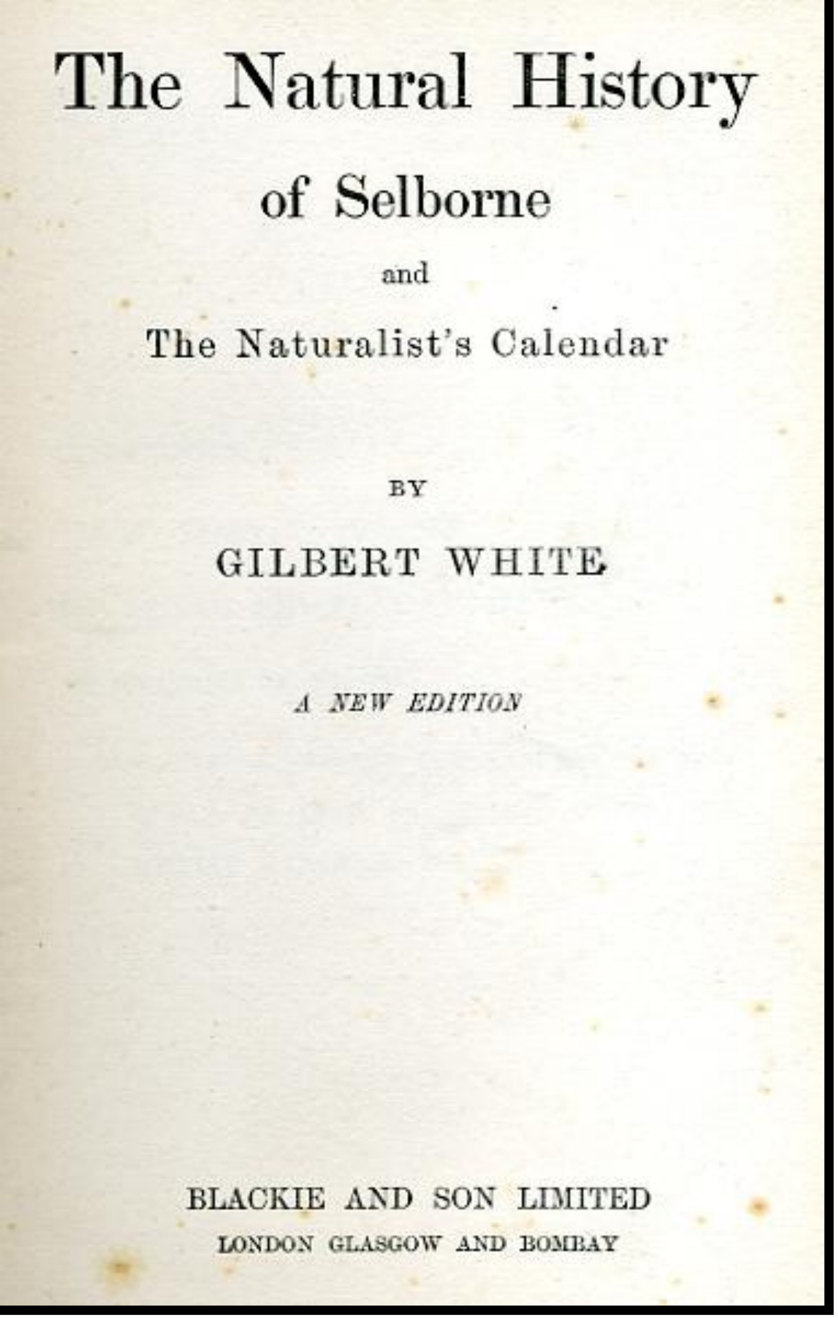
Dr D Dobson, 1777

(I have no idea what the 'D' stands for)

Dobson was amongst the first to expose gauges to today's standards, on a large, open, grassy patch, well exposed all round.

Until then most gauges had been on roofs, it being thought that this would '*record free fall of rain*', the wind problems not yet being appreciated.

The gauge was 30 cm in diameter and was part of a larger experiment concerning evaporation.



The Natural History
of Selborne
and
The Naturalist's Calendar

BY

GILBERT WHITE

A NEW EDITION

BLACKIE AND SON LIMITED
LONDON GLASGOW AND BOMBAY

Gilbert White took rainfall readings in Selborne from 1779 to1786, but considered this not long enough to get a good estimate of mean rainfall.

Year	Total (inches)	Total (mm)
1780	27.32	694
1781	30.71	780
1782	50.26	1277
1783	33.71	856
1784	38.80	986
1785	31.55	801
1786	39.57	1005

A History of raingauges, Ian Strangeways, TerraData Ltd. 2010

The longest record by one person to that time, using the same instrument, was kept by Gilbert White's brother-in-law, Thomas Barker of Lyndon in Rutland, who made observation for 59 years (1736-1796).

He showed how, by taking different periods, the average varied a lot. Variability is a characteristic of the climate that often frustrates attempts to find trends.

The averages, for the periods shown, are in brackets. This demonstrates how variable rainfall is from year to year

1740-63 (419), 1740-50 (470), 1740-63 (514),

1763-96 (648), 1770-80 (660), 1773-75 (813)

William Heberden (1710-1801)

Heberden was doctor in London who experimented with raingauges.

He noticed that gauges higher up caught less and to investigate this he put one in his garden, one on the roof of his house and one on a tower of Westminster Abbey.

He found that the gauge on the roof caught only 80% of that in the garden while the gauge on the tower caught just half.

He concluded that raindrops must increase in size over the last few hundred feet of their fall!

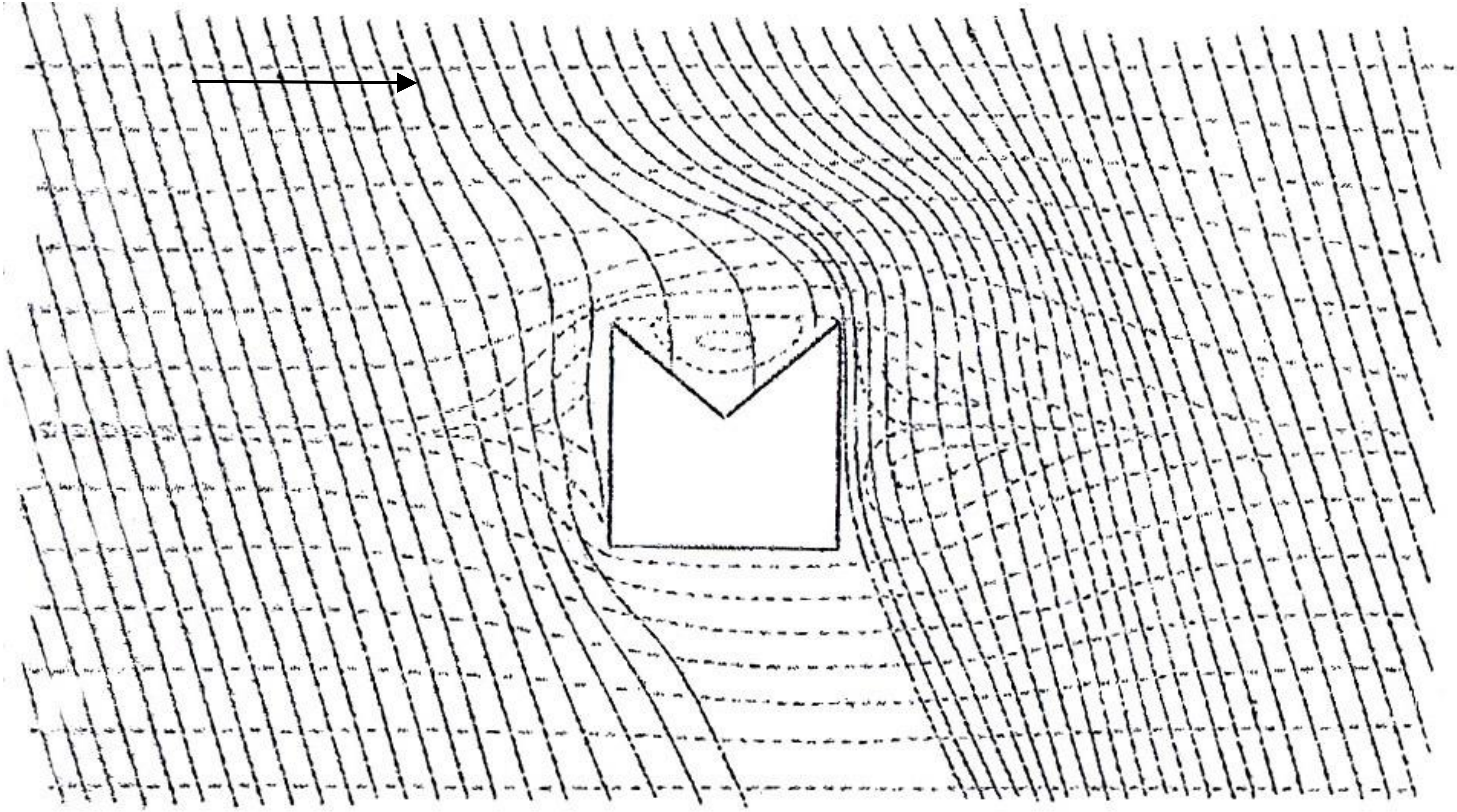
William Stanley Jevons (1835-82)

Jevons was an economist and logician. He worked in Australia for a time and published the first scientific study of the country’s climate in 1859.

In the UK he constructed a glass-sided wind tunnel and observed wind flow over obstructions using smoke, from smouldering brown paper as a tracer. With his tunnel he showed that a rain gauge acts as an obstruction, causing the wind to speed up over the top, thereby carrying some drops beyond the gauge and reducing the catch. The next slide shows the drawing he produced.

At the age of 46, he drowned while swimming.

Jevons's drawing of wind flow over a raingauge



George James Symons (1838-1900)

George Symons is the topic of other talks in this meeting and a central figure in the whole of this meeting. The following points are a summary for the sake of completeness:

- Worked in the Meteorological Department of the Board of Trade (first UK Met Office)
- Became interested in rainfall measurement during the drought years of 1854–8
- Collected rainfall data from many sources and experimented with the gauges then in use.
- In 1860-1861 published the first volume of *English Rainfall*, containing 168 annual totals.
- Resigned his post at the Board of Trade in 1863 to devote all his time to rainfall measurement,
- When he died in 1900, he was receiving records from 3500 sites.
- **Symons is one of the most significant figures in rainfall measurement**

Col Ward and the Rev Charles Griffiths

Ward did field tests in the 1860s to investigate the best diameter and height of a gauge.

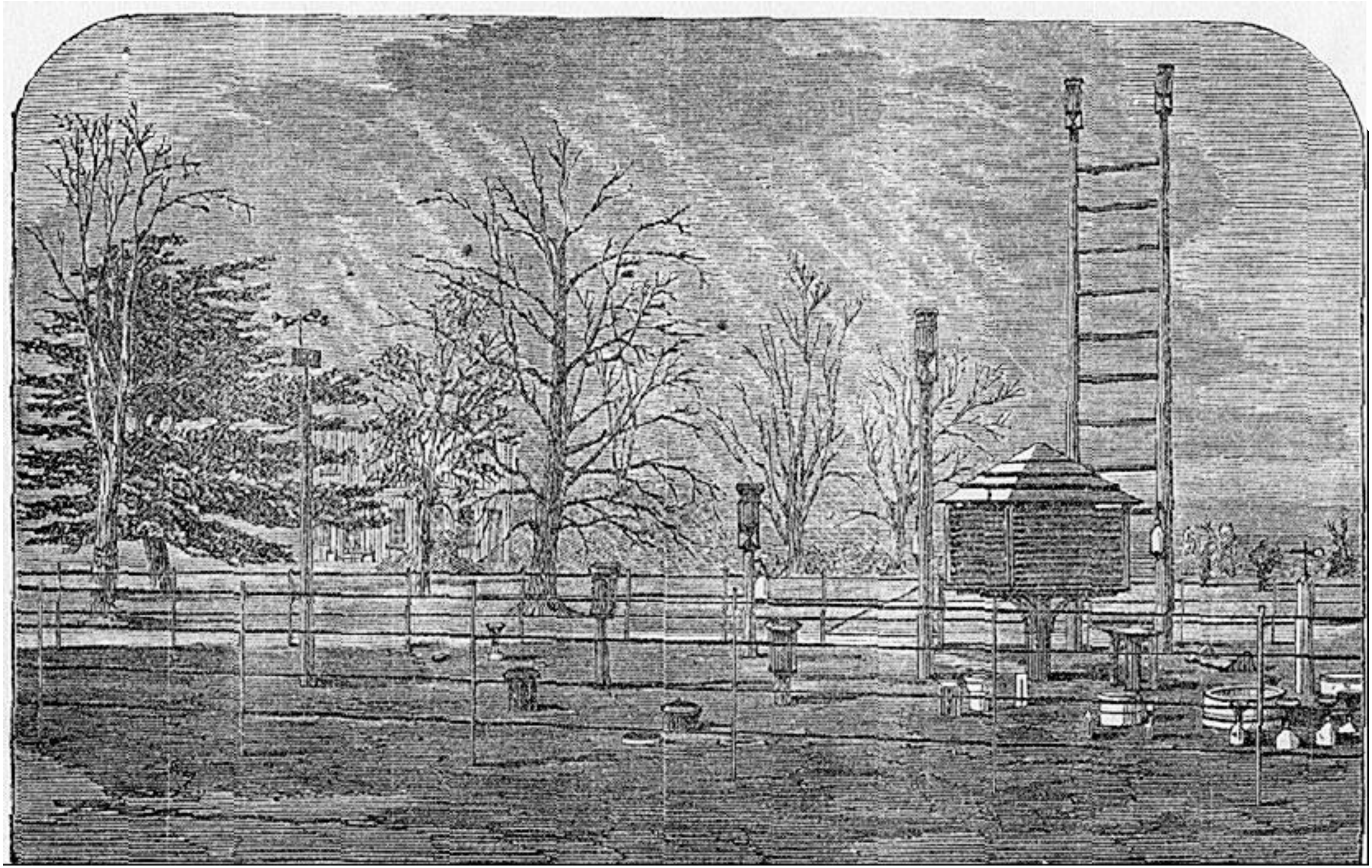
The Rev Charles Griffiths continued this work comparing around 50 gauges.

Their tests confirmed the effects of wind.

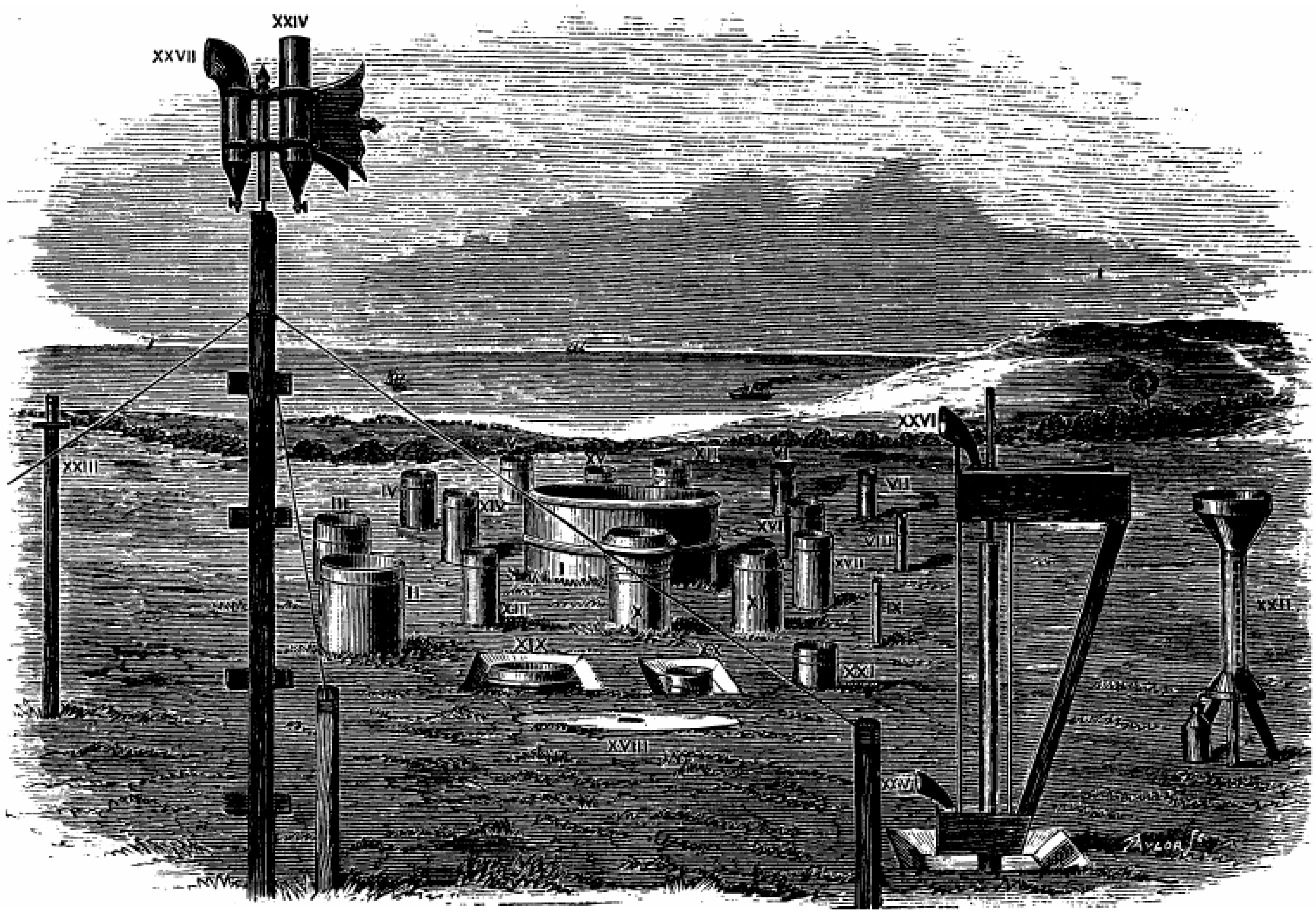
The tests also resulted in the standard five inch raingauge

So far, all research had been done by private individuals, as was much science at this time.

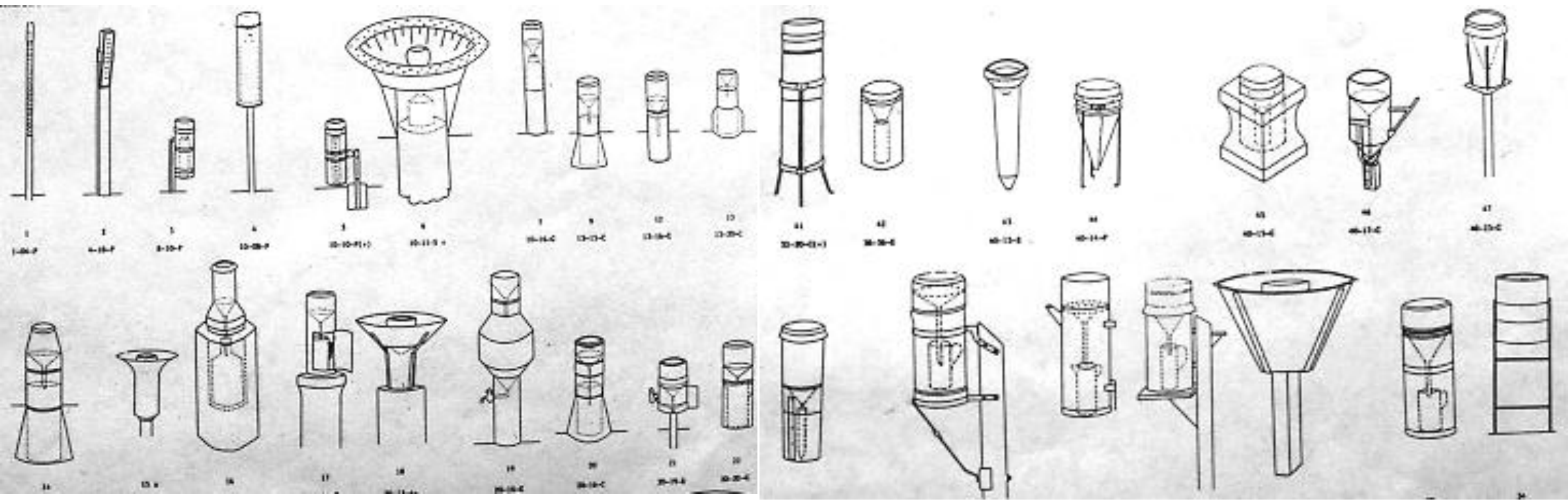
Experimental gauges operated in the 1860s by Col Ward at Calne in Wiltshire, investigating the effects of height on rainfall measurement



Intercomparison of raingauges in the 1870s at a site operated by F. W. Stow at Hawsker, near Whitby, Yorkshire



Contemporary raingauges
Manual gauges



There are numerous designs of raingauge, all with different errors

The UK Met Office Mark 2, five inch, raingauge

The UK standard

Stores water equivalent to 75 mm rain

Is read daily using a graduated measuring cylinder.

Larger bases allow weekly or monthly amounts of rain to be stored, one holding 680, another 1270 mm.

Mechanical recording gauges

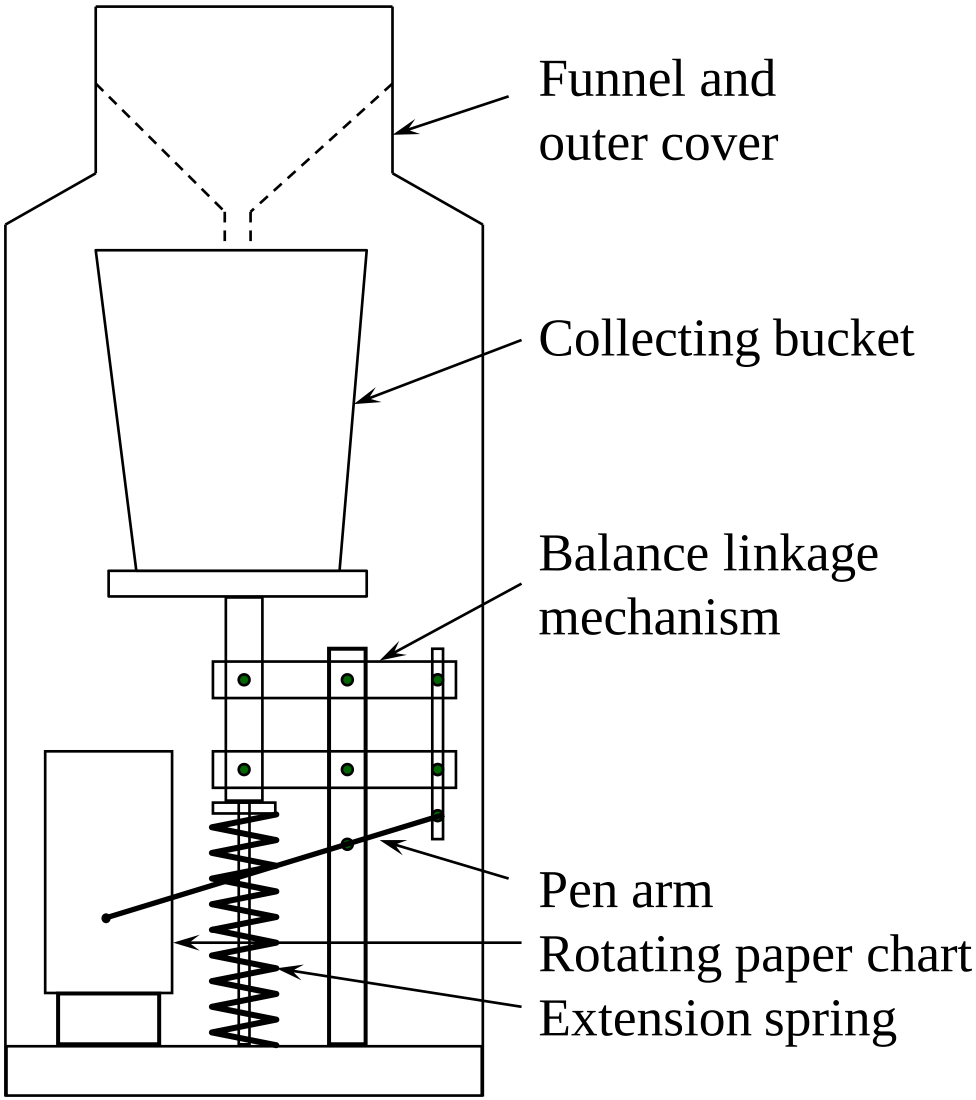
Tilting siphon gauge by Dines (1920)

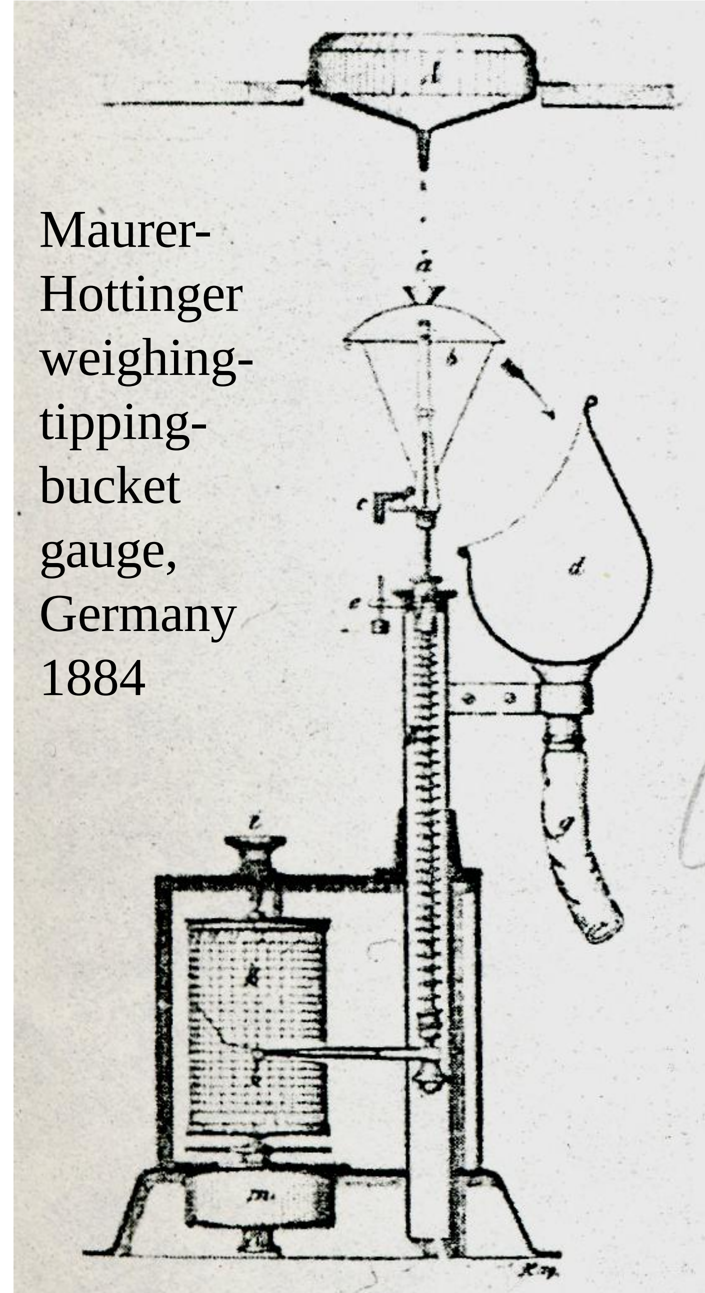
Others include:

The ‘natural siphon’ recorder of Negretti and Zambra

The Hellmann siphon gauge

Weight-operated recorders

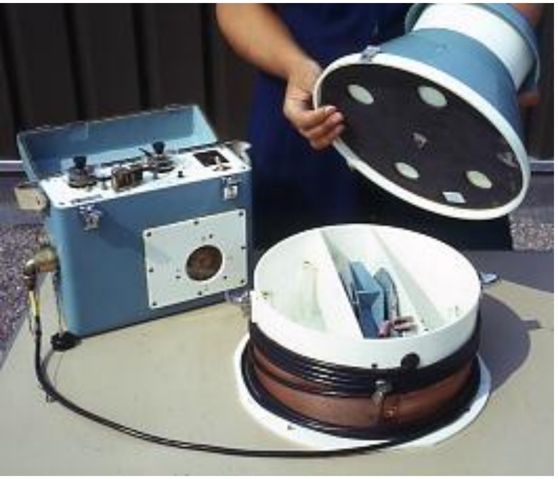




Maurer-Hottinger weighing-tipping-bucket gauge, Germany 1884

Electrical raingauges

Tipping bucket gauges

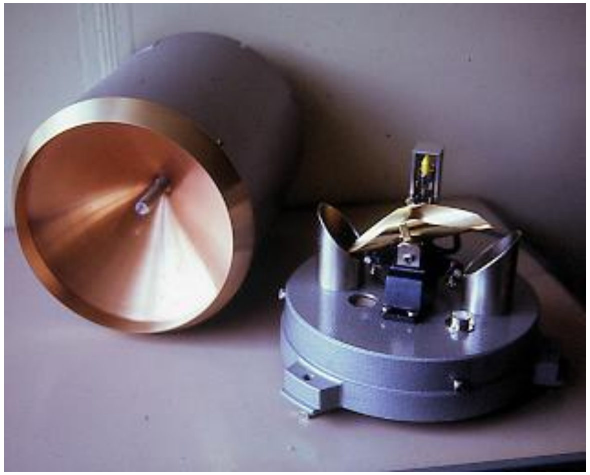


Plessey, UK, 1960s

Tipping bucket mechanism

Didcot Instruments, UK

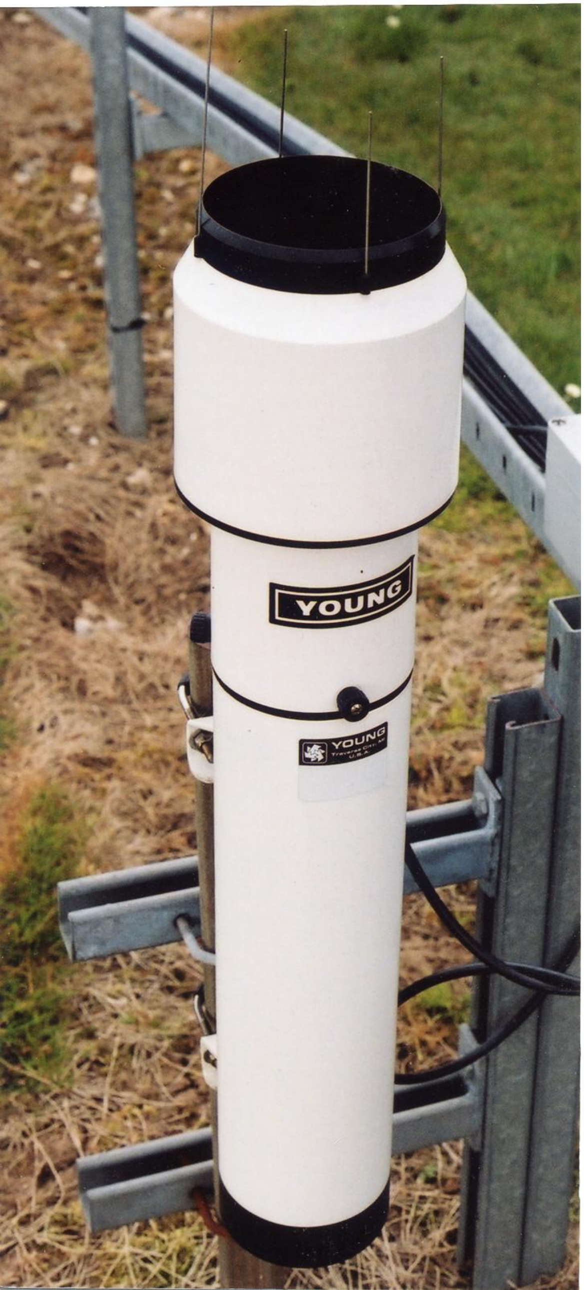
Russia, gimbals, 1970s



'Rimco', Australia 1970s

Environmental Measurements , UK

Capacitance raingauge



This is a recent development

The collected water is held it in a cylinder containing electrodes acting as the plates of a capacitor

The dielectric constant of water is around 80 and that of air 1

By including the capacitor in a tuned circuit, the depth of water can be measured.

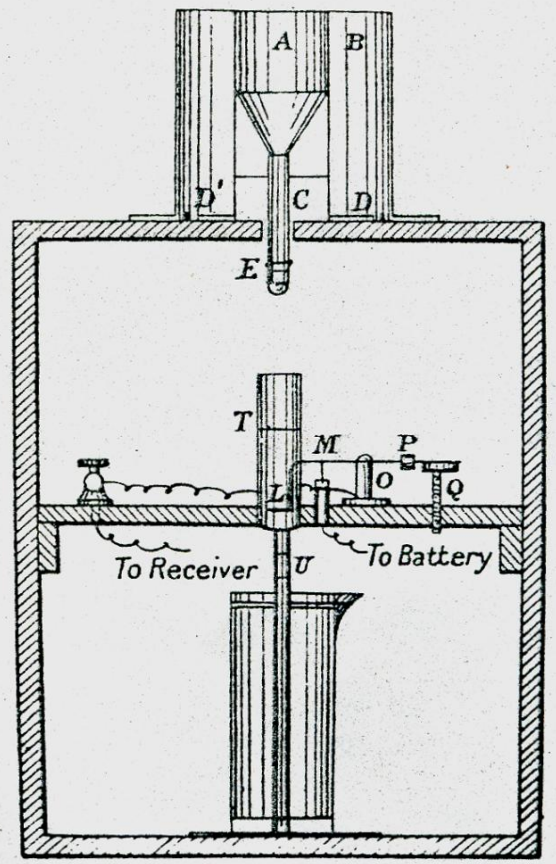
This type of gauge is currently used on buoys in the equatorial Pacific and Atlantic oceans in the Tropical Atmosphere and Ocean (TAO) project

Radar Raingauges

Not to be confused with Weather Radar, which uses scanning dishes to measure precipitation over large areas, a recent new introduction is the use of very small Doppler radars, similar to those used for traffic detection, working at around 11GHz. These upward-looking instruments measure the spectrum of backscatter from falling raindrops and this indicates their fall velocity and thus drop size. An algorithm converts the signal to rainfall intensity and then to totals, typically from 1 minute to ten minutes.

Microphotograph of raindrops collected in oil during a thunderstorm. There can be a great range of drop sizes in any rain event (as illustrated) and the radar has to detect the full spectrum. Wind will also influence the drop velocity so the algorithm has to deal with a complex signal,

Drop-counting raingauges

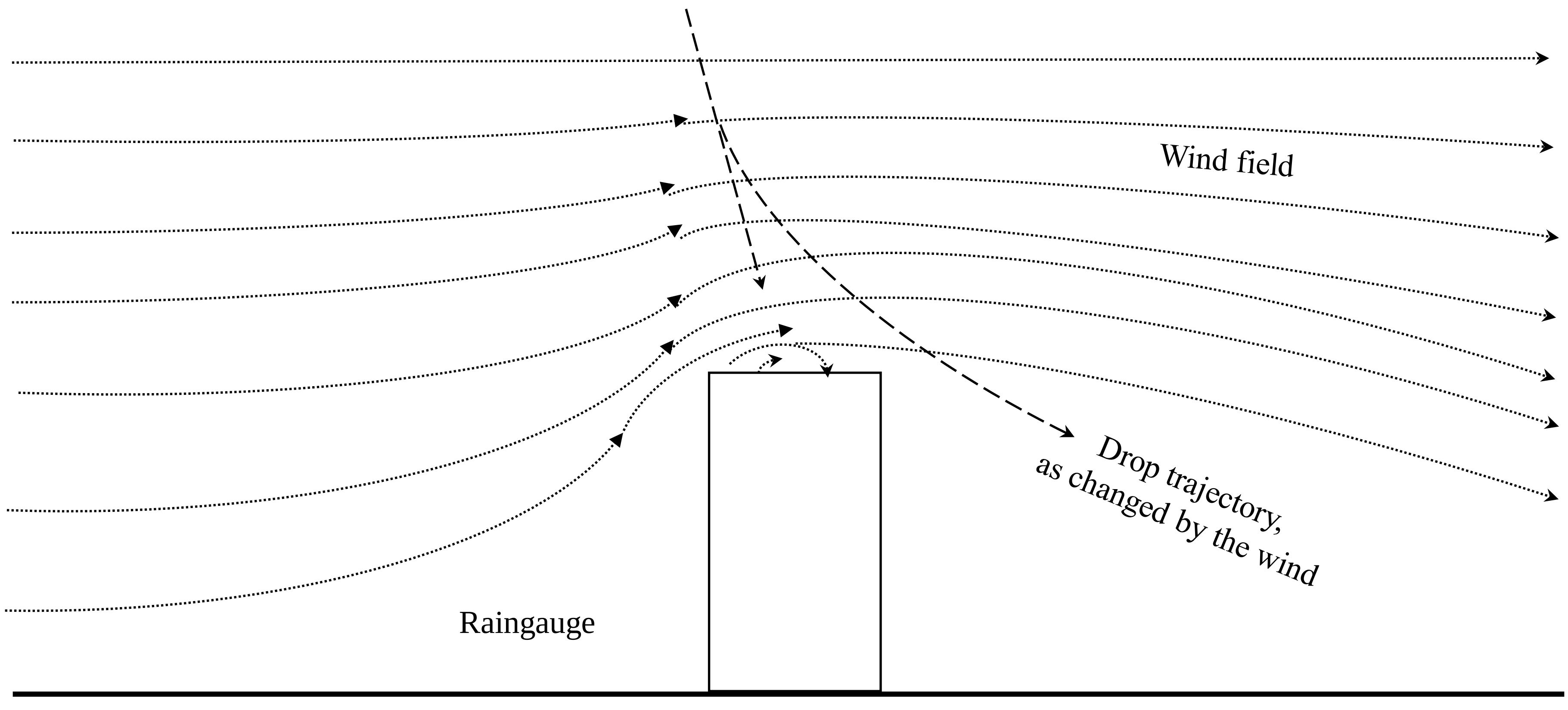


Binnie drop recorder, 1892, England.

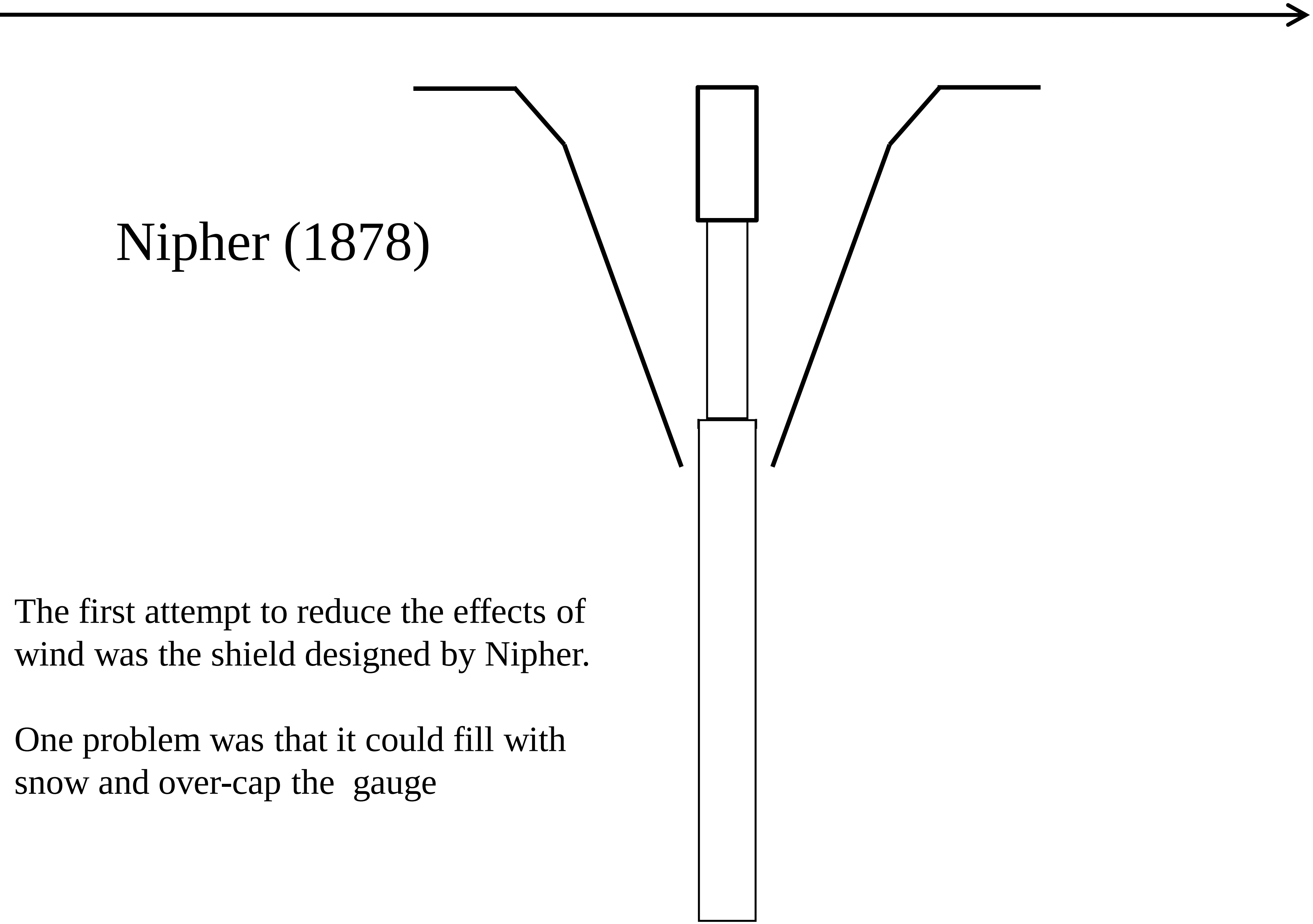
Converting the collected water into drops and counting the drops is a technique that was developed in the 19th century, as illustrated. Modern versions have been developed but it is not widely used, one reason being that the size of the drops varies by several percent as the surface tension varies with temperature. It has the advantage, however, that it provides a good measure of rainfall intensity. However, there are few modern raingauges based on this principle.

Combating the wind errors

The wind speeds-up when passing over the top of a gauge, carrying drops that should have fallen in the gauge beyond it.



Nipher (1878)



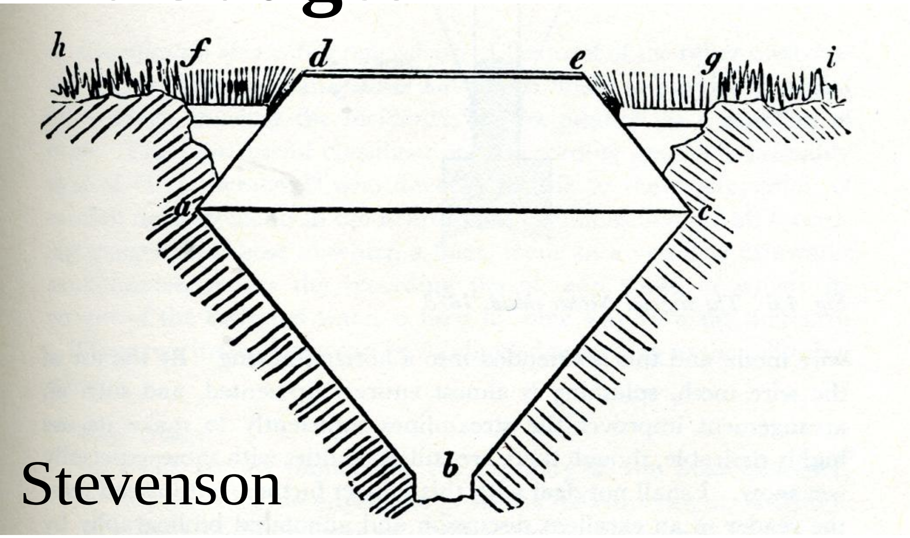
The first attempt to reduce the effects of wind was the shield designed by Nipher.

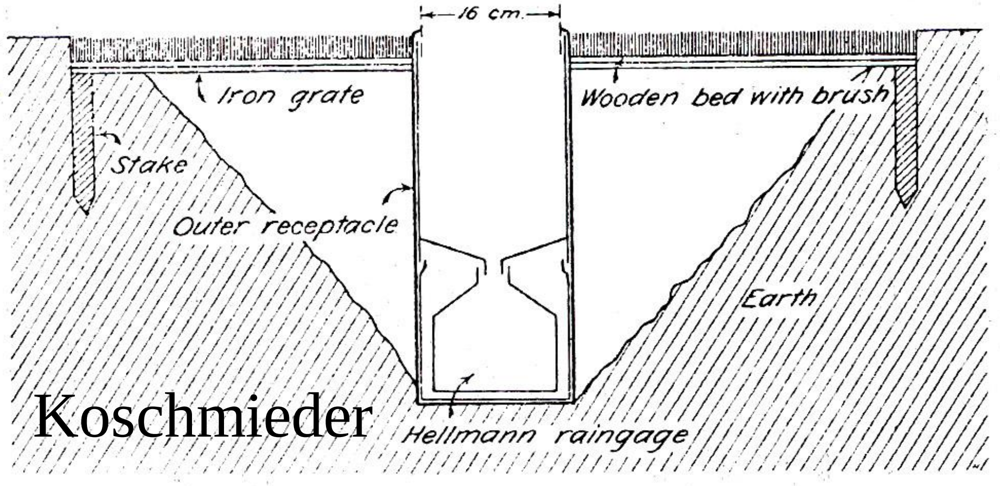
One problem was that it could fill with snow and over-cap the gauge

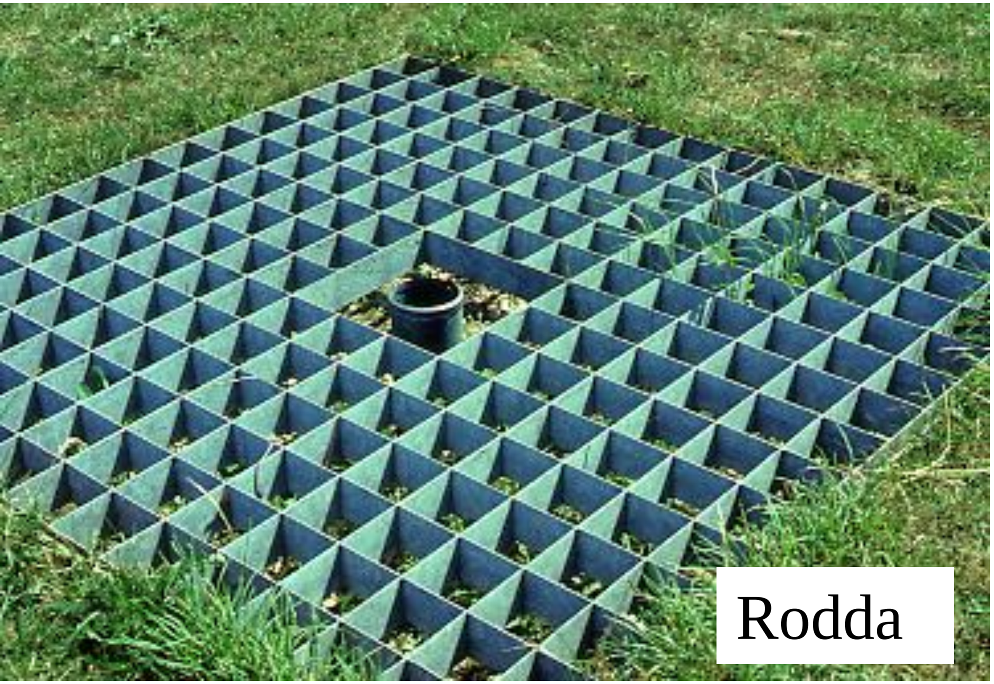
Turf Wall - Huddleston

In the Lake District in the UK, Huddleston carried out extensive tests in the mountains searching for the best exposure for a gauge and designed the turf-wall. This has been widely used but it too can fill with snow

Pit Gauges







The best exposure for a gauge is at ground level in a pit surrounded by an anti-splash surface such as a bristle matt (above) or a grating (as left). The grating was used extensively by the Institute of Hydrology (IH) (now the Centre for Ecology and Hydrology) in order to obtain precise measurements of 'input' for long-term investigations studying the water balance of different catchments, the run-off, evaporation and groundwater also being measured.

Aerodynamic raingauges

Top, left shows two aerodynamic 5” gauges tested by IH in the 1960s. Bottom left shows two 10” plastic tipping bucket aerodynamic raingauges which I designed in the 1980s while at IH. The below figure shows my 2004 design starting from the Folland mathematical, theoretical design modified to avoid outsplash. Now manufactured by Environmental Measurements Ltd. See later.

Optical Raingauges

Optical raingauges, or 'Present Weather Detectors' ,sense raindrops passing through a light beam and convert the scintillating signal into rainfall intensity. Good with rain, less so with snow. They are spin-offs from visibility meters.

Rainfall measurement over the oceans

71% of the globe is covered by the sea

There are very few measurements from here

Mostly just from a few islands

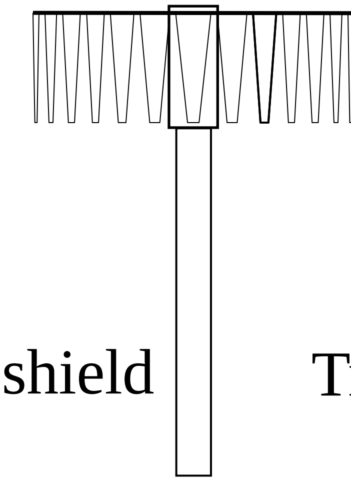
But the islands can affect the local climate

And there are few measurements from the polar regions or mountains

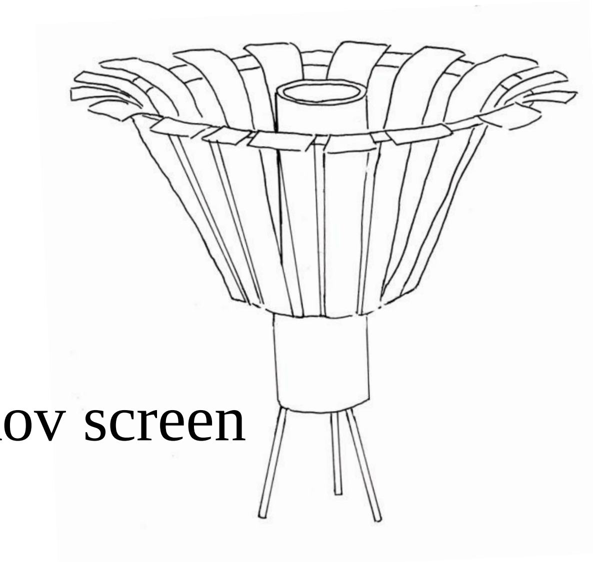
So we only have measurements from about 25% of the globe

Measuring Snowfall

Windshields For Snowgauges



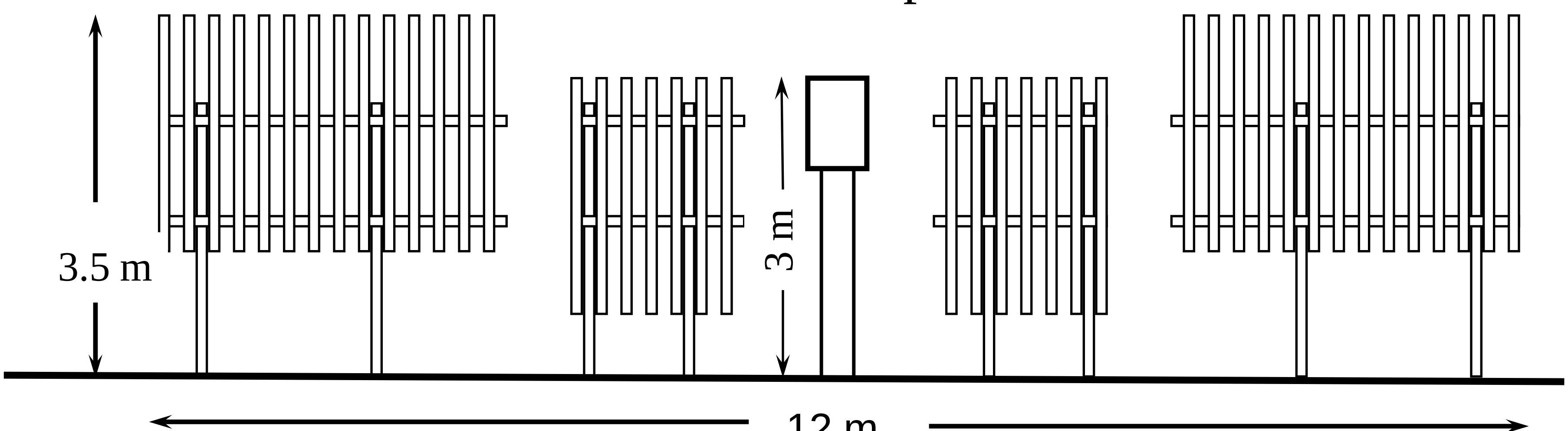
Alter shield



Tretyakov screen

The wind errors are much greater in the case of snowfall. The three most common snowfall windshields are illustrated. The WMO shield is very large and is used mostly as a reference against which to compare other techniques.

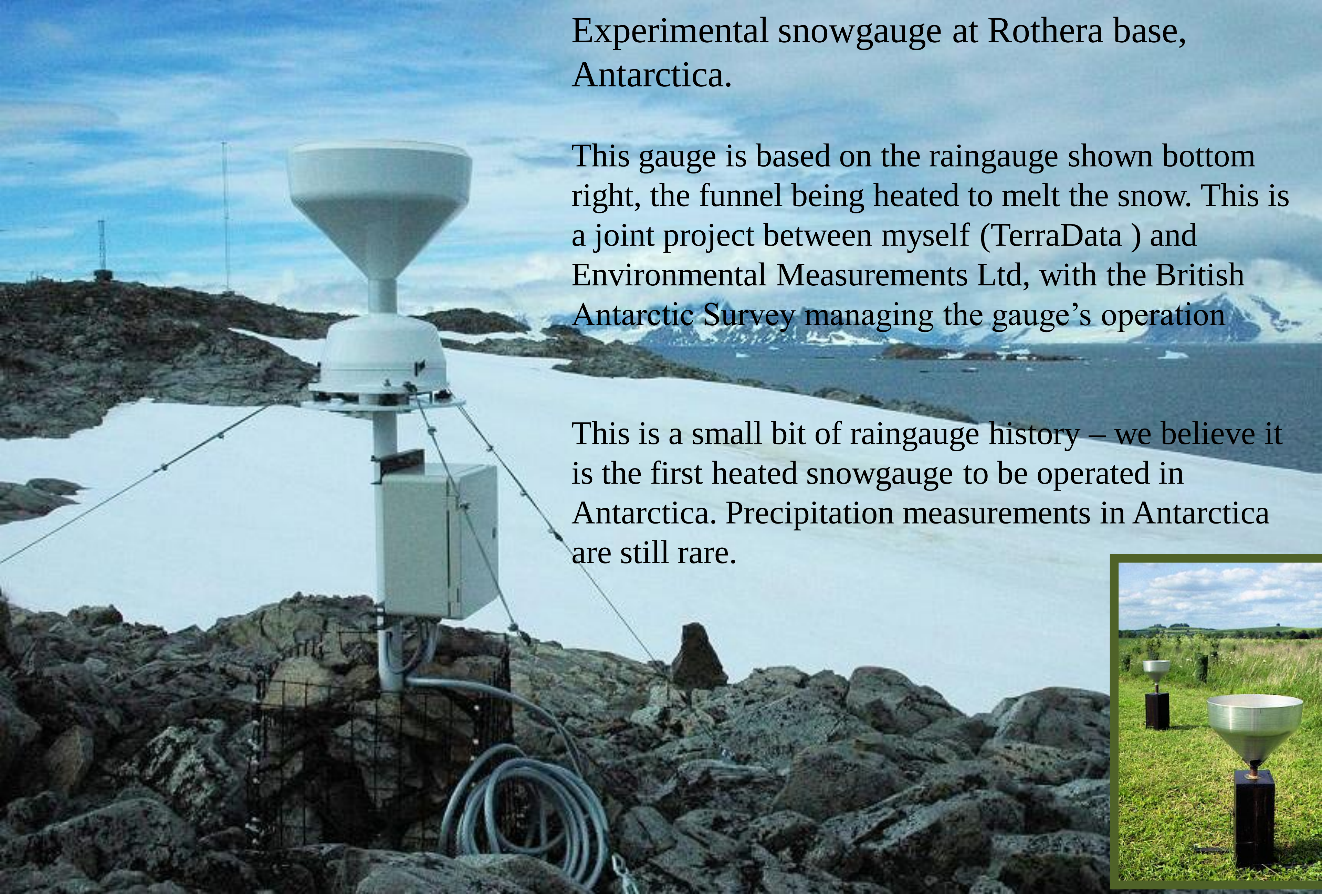
WMO Double Fence Intercomparison Reference Shield



Experimental snowgauge at Rothera base, Antarctica.

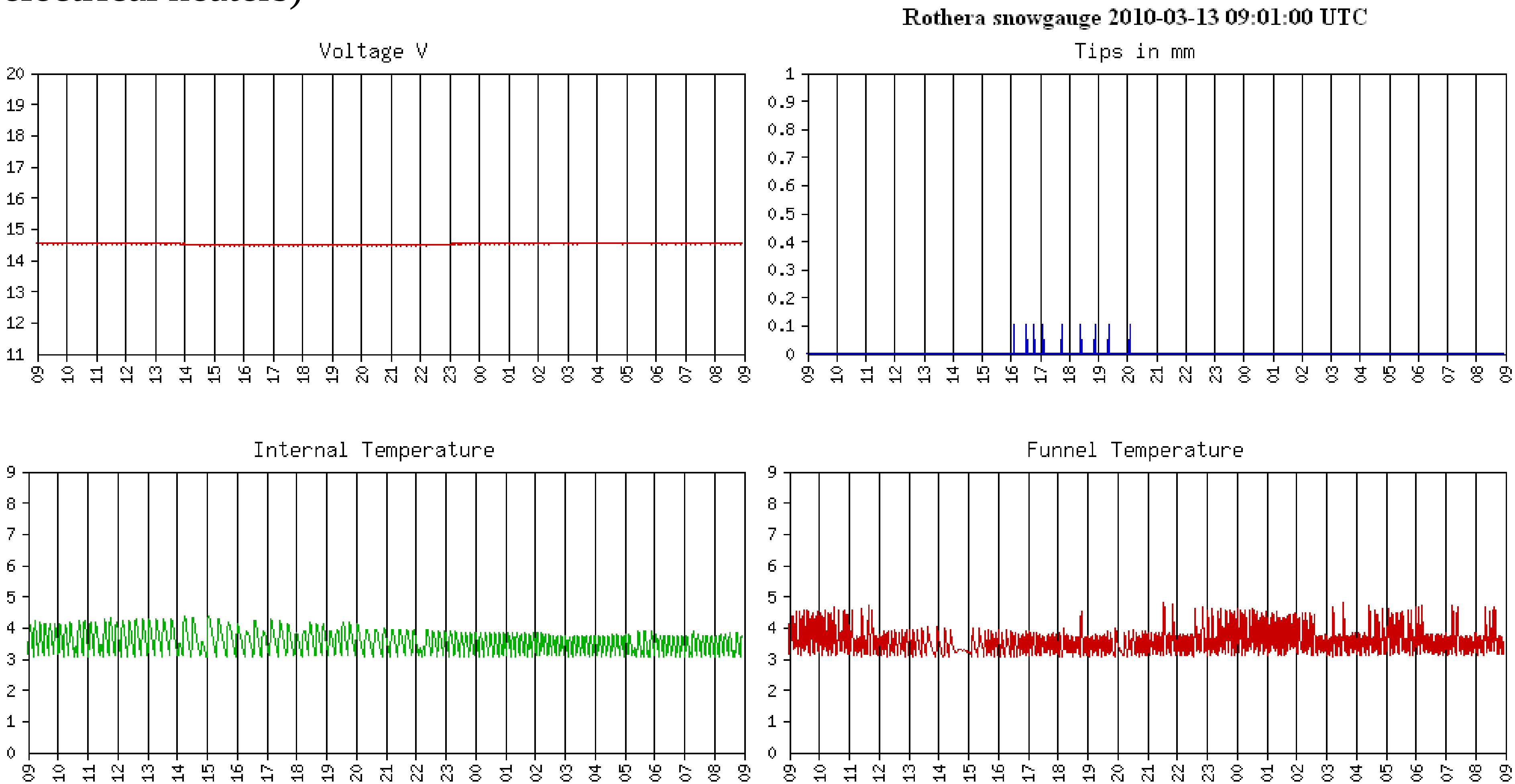
This gauge is based on the raingauge shown bottom right, the funnel being heated to melt the snow. This is a joint project between myself (TerraData) and Environmental Measurements Ltd, with the British Antarctic Survey managing the gauge's operation

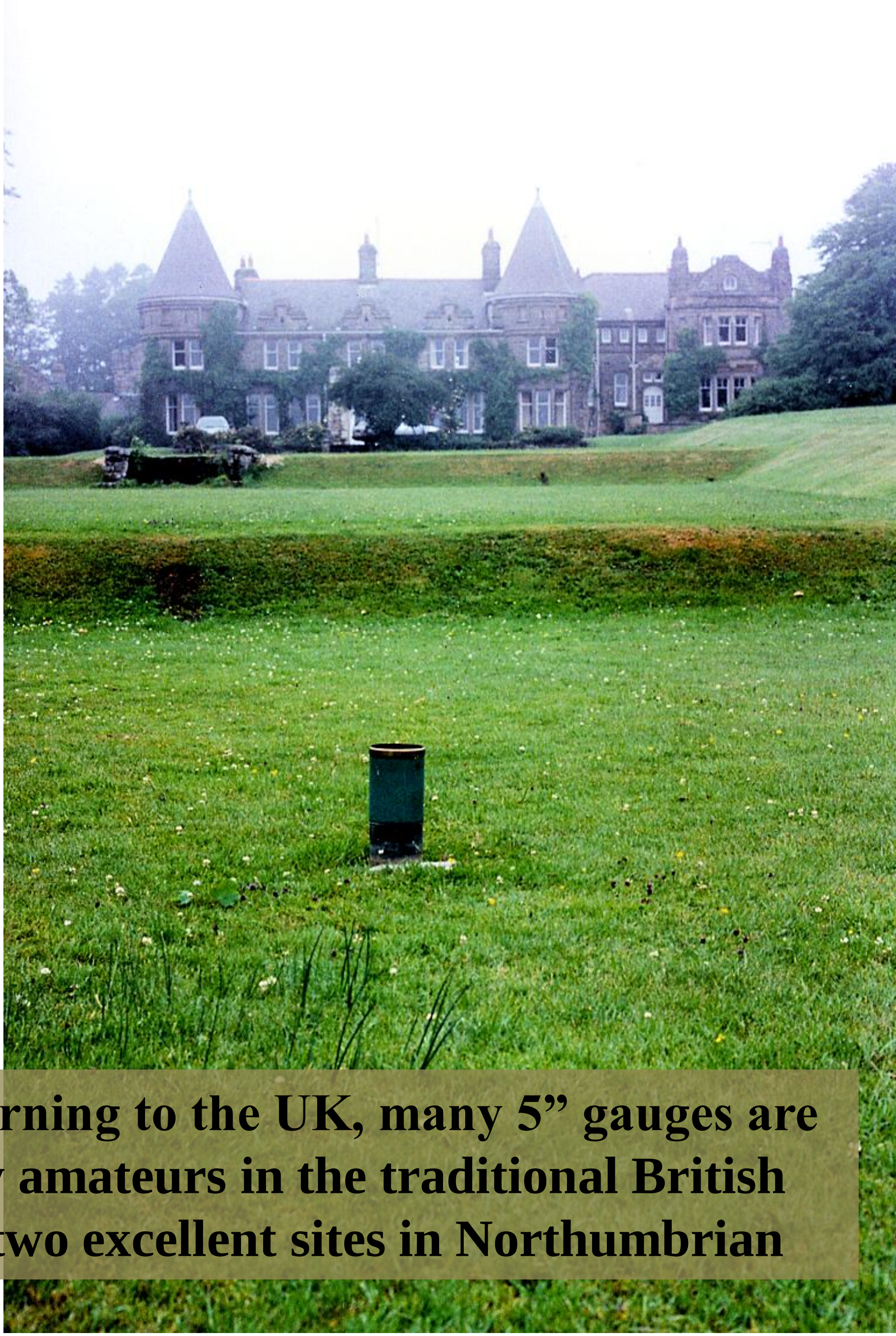
This is a small bit of raingauge history – we believe it is the first heated snowgauge to be operated in Antarctica. Precipitation measurements in Antarctica are still rare.



Photograph by Jonathan Shanklin.

Plots from the snowgauge shown in the previous slide, showing the battery voltage, the tips of the tipping bucket (0.9 mm in this case), the temperature of the funnel and of the heated bucket cavity (both maintained independently at a minimum of + 3ºC by electrical heaters)



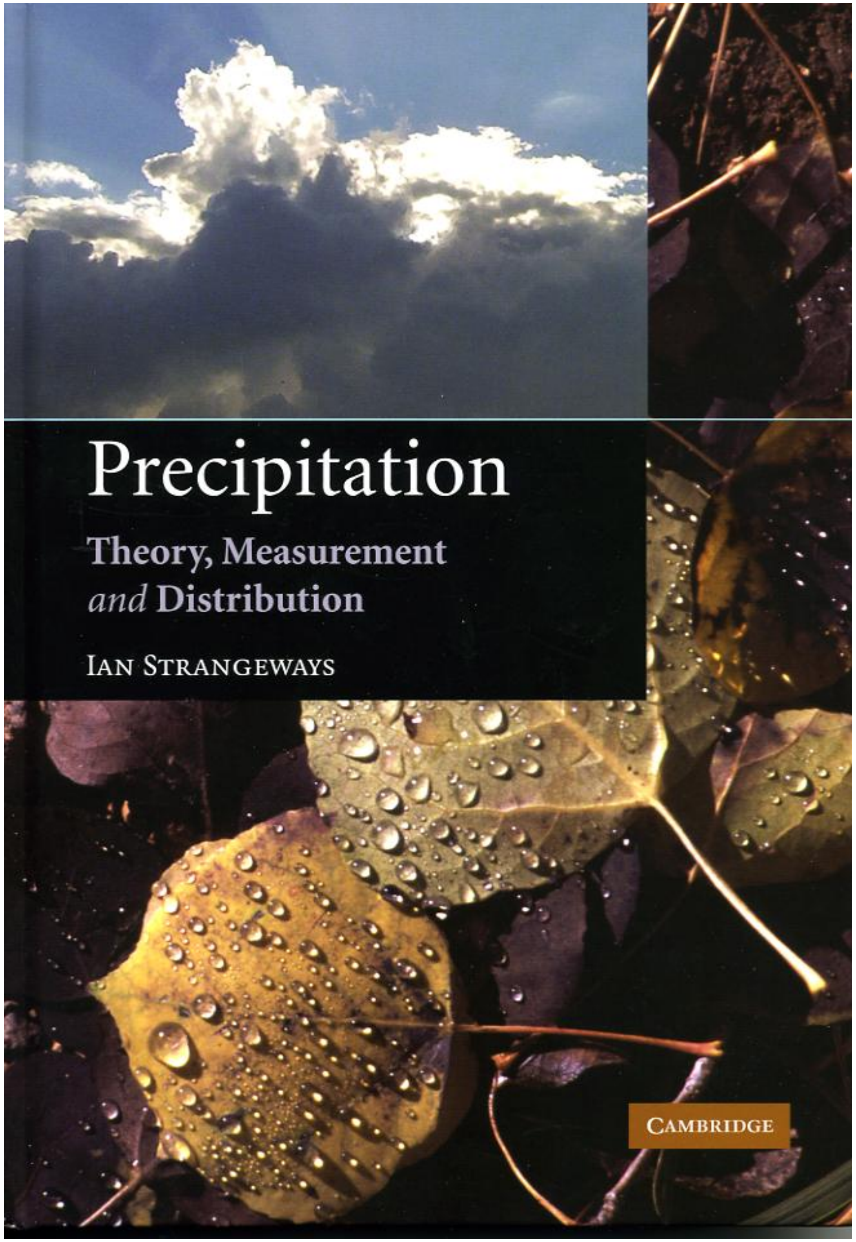


To conclude, returning to the UK, many 5” gauges are still operated by amateurs in the traditional British way, as here at two excellent sites in Northumbrian

Readers wanting more detailed information can find it in my book. See:

www.cambridge.org/9780521851176

This book will also be available in paperback from around September 2010.



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