Beaufort

National Meteorological Library and Archive
Fact sheet 6 — The Beaufort Scale

(version 01)

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Introduction

It is often said that Francis Beaufort, of the British Royal Navy, was the first to devise a scale of wind force – towards the start of the 19th century. However, in reality he was not, in fact, the originator of such a scale. A similar one was actually in use at least a century earlier – and probably long before that.

We do not know who first devised a scale of wind force. But it would be surprising if medieval Arab seafarers did not use one because they had, by the late 15th century, classified in detail virtually every aspect of the weather that had any navigational significance.

It would be surprising, too, if the mariners of ancient times did not use such a scale – but as they left so few records, we can only speculate.

The scale we all know – the one that bears Beaufort's name – was formulated at the start of the 19th century. But accounts from 1704 show that a similar scale was in use a century earlier.

Daniel Defoe's 'Table of Degrees'

Daniel Defoe, in his account of the dreadful tempest that visited the British Isles on 26–27 November 1703, entitled 'A Collection of the most remarkable Casualties and Disasters which happen'd in the late dreadful Tempest both by Sea and Land', referred to a 12-point scale that he called a 'table of degrees'. This comprised, as he put it, "bald terms used by our sailors":

Defoe's 'table of degrees':

- Stark calm
- Calm weather
- Little wind
- A fine breeze
- A small gale
- A fresh gale
- A topsail gale
- Blows fresh
- A hard gale of wind
- A fret of wind
- A storm
- A tempest

Figure 1. Daniel Defoe (c1661 to 1731)

Colonel Capper's 'Table of velocities and forces of the wind'

By the beginning of the 19th century, a quantitative version of a wind scale had been devised, as a work by Colonel Capper of the East India Company shows. In his 'Observations on the winds and monsoons', 1801, he reproduced "A table of the different velocities and forces of the winds, constructed by Mr Rous, with great care, from a considerable number of facts and experiments".

Terms of the wind	Velocity of wind		Perpendicular force on one square foot in Avoirdupois pounds
	Miles in one hour	Feet in one second	
Almost calm	1	1.47	0.005
Just perceptible	2 3	2.93 4.40	0.020 0.044
Gentle breeze	4 5	5.87 7.33	0.079 0.123
Fresh breeze	10 15	14.64 22.00	0.492 1.107
Fresh gale	20 25	29.34 36.67	1.968 3.075
Strong gale	30 35	44.01 51.34	4.429 6.027
Hard gale	40 45	56.68 66.01	7.873 9.963
Storm	50	75.35	12.300
Violent hurricanes, tempests, etc.	60 80 100	88.02 117.36 146.70	17.715 31.490 49.200

Table 1. Velocities and forces of the wind by Mr Rous.

From 1660 onwards, keeping weather records at places on land became increasingly popular, and as early as 1723 James Jurin (1684–1750), then Secretary of the Royal Society, recommended a scale for observers to estimate and record wind strength.

Sixty years later, in the Ephemerides published in the 1780s by the Palatine Meteorological Society of Mannheim – the world's first meteorological society – there appeared the following scale, in which halves were used to denote intermediate strengths.

Number	Specification
0	Calm
1	Leaves rustle
2	Small branches move
3	Large branches in motion and dust swirls up from the ground
4	Twigs and branches break off trees

Table 2. Wind scale as used in 1780.

Admiral Beaufort's 'Scale of wind force'

Francis Beaufort devised his scale of wind force in 1805, when serving aboard HMS Woolwich, and first mentioned it in his private log on 13 January 1806, stating that he would, "hereafter estimate the force of the wind according to the following scale".

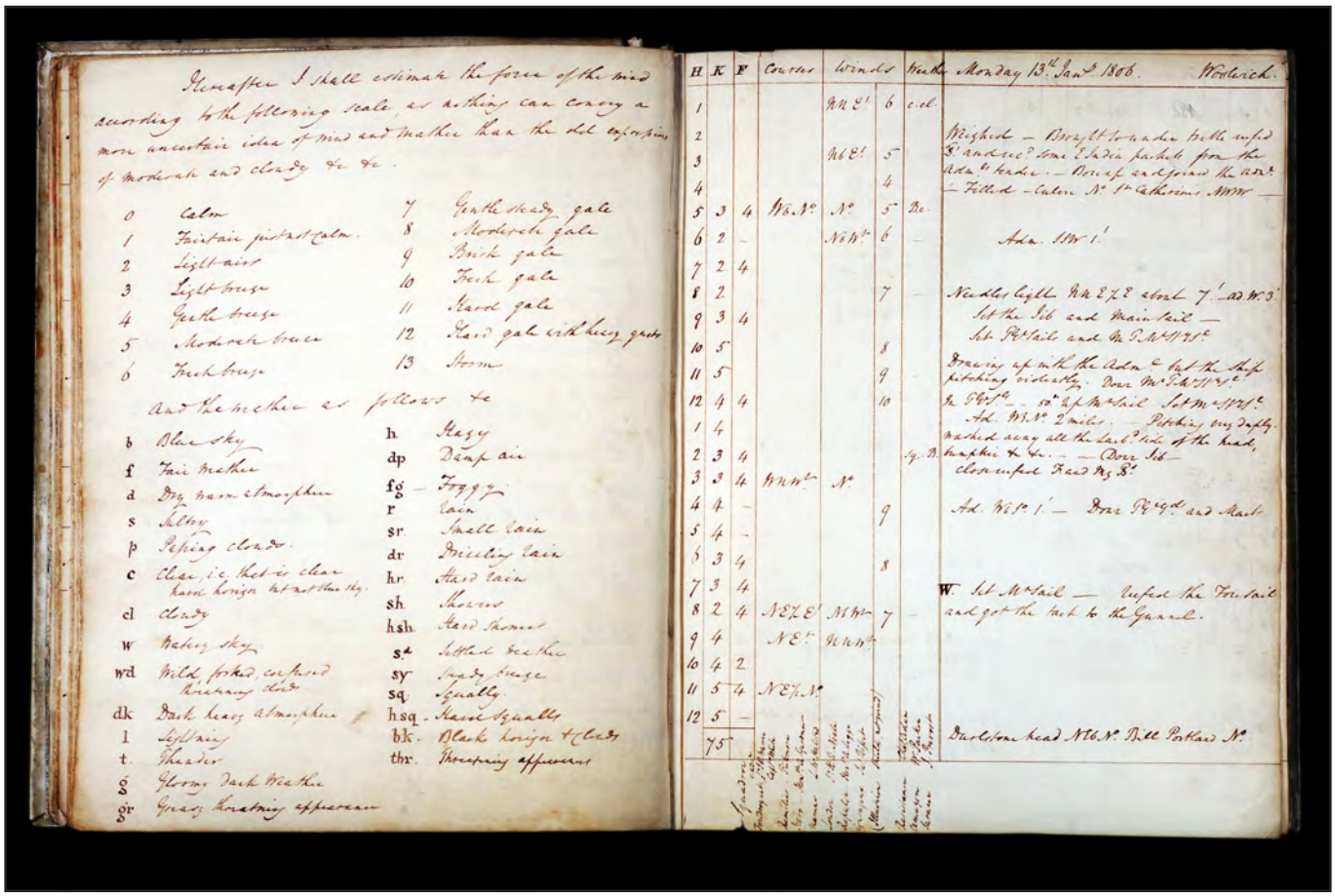


Figure 2. Beaufort's diary from 1806 showing his original scale.

Beaufort modified his scale in 1807, when he decided to combine categories 1 and 2 and thereafter used a scale extending from 0 to 12. In the same year, he added a description of the canvas that could be carried by a fully rigged frigate in different wind conditions. Like the observers of the Palatine Meteorological Society, he frequently used halves, which suggests he was confident he could estimate wind force accurately.

Who was Beaufort?

Francis Beaufort was born in Ireland in 1774, and went to sea in 1787. He took command of HMS Woolwich in 1805. His seagoing career ended in 1812 when he was severely wounded in an encounter with Turks, while surveying the coast of Asia Minor.

After convalescence, he pursued a number of scientific interests until, in 1829 when he was appointed Hydrographer of the Navy.

At the time, he held the rank of captain. In 1831, Beaufort commissioned the celebrated voyage of the Beagle. During the voyage (December 1831 to October 1836), Beaufort's scale of wind force was used officially for the first time.

Beagle's commander, Robert FitzRoy, subsequently became, in 1854, the first director of the body now known as the Met Office. He and Beaufort were close friends for many years.

Beaufort was made a rear-admiral on the retired list in 1846, served as Hydrographer until 1855 and died in 1857.

Figure 3. Admiral Frances Beaufort

A 'private' scale

For many years, Beaufort's scale of wind force was used only in his private logs. There is no mention of it in the official logs of HMS Woolwich or any other ships on which he served. Nor is there any mention of his scale of weather notation, also devised in 1805.

In this notation, he assigned letters to weather types, examples being:

b – blue sky

r – rain

fg – foggy

cl – cloudy

sh – showers

A full and comprehensive list of the Beaufort letters can be found in fact sheet 11 – interpreting weather charts. These became known as the Beaufort Letters.

The first published reference to Beaufort's scales of wind force and weather notation came in 1832, when the Nautical Magazine carried an article entitled 'The Log Board'.

In this article, formulation of the scales was attributed to Beaufort, and the versions of the scales discussed were identical to those introduced later by the Admiralty in a memorandum issued in December 1838 to 'all Captains and Commanding Officers of Her Majesty's Ships and Vessels'.

Admiralty, Dec 28th, 1838

MEMORANDUM.

The Lords Commissioners of the Admiralty having had under consideration the general utility of recording with clearness and precision, in the Log Books of all Her Majesty's Ships and Vessels of War, the actual State of the Winds and Weather, have thought fit to order that henceforward in each page of the Log Book two columns should be introduced, wherein the force of the Wind and the appearance of the Atmosphere shall be every hour registered according to the annexed scheme, a copy of which shall be pasted into each book and painted on the back of every Log Board or Log Slate and two more columns shall likewise be given for the purpose of entering the heights of the Barometer or Sympiesometer, and Thermometer, when such instruments may be on board.

By Command of their Lordships,

C. WOOD

Figure 4. Admiralty memorandum, 28 December 1838.

To denote the force of the wind and the state of the weather, Royal Navy officers were ordered to use the scales below.

Beaufort number	General description	Beaufort's criterion	
0	Calm	Calm	
1	Light air	Just sufficient to give steerage way	
2	Light breeze	With which a well-conditioned man of war, under all sail, and 'clean full', would go in smooth water from...	1 to 2 knots
3	Gentle breeze		3 to 4 knots
4	Moderate breeze		5 to 6 knots
5	Fresh breeze	In which a well-conditioned man of war, under all sail, and 'clean full', could just carry close hauled...	royals
6	Strong breeze		single-reefs and top-gallant sails
7	Moderate gale		double-reefs, jib, etc.
8	Fresh gale		triple-reefs, courses, etc.
9	Strong gale		close-reefs and courses
10	Whole gale	With which she could only bear close-reefed maintop-sail and reefed fore-sail	
11	Storm	With which she would be reduced to storm staysails	
12	Hurricane	To which she could show no canvas	

Table 3. Beaufort's criterion 1832.

An evolving system

Beaufort's scale of wind force was revised in 1874 to reflect changes in the rig of warships, and expanded two decades later to include particulars of the sail required by fishing smacks. A scale of equivalent wind speeds was introduced in 1903, its basis being the formula:

$V = 1.87 \times \text{square root } (B^3)$

where:

B is the Beaufort number, and

V the corresponding wind speed in miles per hour 30 feet above the surface of the sea.

By the early 20th century, the passing of sail made a specification based on the canvas carried by a sailing ship impractical. British meteorologist George Simpson proposed an alternative, a scale of wind force based on the sea's appearance. It was devised in 1906 and soon accepted by mariners and meteorologists, but it was not adopted by the International Meteorological Organization until 1939.

The Beaufort scale was extended in 1944, when Forces 13 to 17 were added. Before that, Force 12 (Hurricane) had been the highest point on the scale, referring to a sustained wind speed of 64 knots (32.7 metres per second) or more – that is, the wind speed averaged over a period of 10 minutes.

The additional five points extended the scale to 118 knots (61.2 metres per second), with Force 12 referring only to speeds in the range 64 to 71 knots (32.7 to 36.9 metres per second). However, Forces 13 to 17 were intended to apply only to special cases, such as tropical cyclones. They were not intended for ordinary use at sea – indeed, it is impossible to judge Forces 13 to 17 by the appearance of the sea.

For all normal purposes, the Beaufort scale extends from Force 0 (calm) to Force 12 (Hurricane), with Force 12 defined as a sustained wind of 64 knots (32.7 metres per second) or more.

Beaufort's scale of wind force assumed its present form around 1960, when probable wave heights and probable maximum wave heights were added. The latter is the height of the highest wave expected in a period of 10 minutes, and wave heights refer to the open sea, well away from land.

Strictly, it applies only when the sea is fully developed; that is, when waves have reached their maximum height for a particular wind speed. Care must be exercised when the fetch and duration of the wind are limited (the fetch is the distance over which the wind has blown, and the duration the time it has been blowing). It is also worth remembering that the appearance of the sea's surface is influenced not only by wind but also by swell (waves from far away), precipitation, tidal streams and other currents.

Force	Description	Specification for use at sea*	Equivalent speed at 10 metres above sea level				Description in forecast	State of sea	Probable height of waves* /metres
			Mean		Limits				
			/knots	/ms^{-1}	/knots	/ms^{-1}			
0	Calm	Sea like a mirror	0	0.0	<1	0.0 to 0.2	Calm	Calm	0.0
1	Light air	Ripples with the appearance of scales are formed, but without foam crests	2	0.8	1 to 3	0.3 to 1.5	Light	Calm	0.1 (0.1)
2	Light breeze	Small wavelets, still short but more pronounced. Crests have a glassy appearance and do not break	5	2.4	4 to 6	1.6 to 3.3	Light	Smooth	0.2 (0.3)
3	Gentle breeze	Large wavelets. Crests begin to break. Foam of glassy appearance. Perhaps scattered white horses	9	4.3	7 to 10	3.4 to 5.4	Light	S mooth	0.6 (1.0)
4	Moderate breeze	Small waves, becoming longer, fairly frequent white horses	13	6.7	11 to 16	5.5 to 7.9	Moderate	Slight	1.0 (1.5)
5	Fresh breeze	Moderate waves, taking a more pronounced long form; many white horses are formed. Chance of some spray	19	9.3	17 to 21	8.0 to 10.7	Fresh	Moderate	2.0 (2.5)
6	Strong breeze	Large waves begin to form; the white foam crests are more extensive everywhere. Probably some spray	24	12.3	22 to 27	10.8 to 13.8	Strong	Rough	3.0 (4.0)
7	Near gale	Sea heaps up and white foam from breaking waves begins to be blown in streaks along the direction of the wind	30	15.5	28 to 33	13.9 to 17.1	Strong	Very rough	4.0 (5.5)
8	Gale	Moderate high waves of greater length; edges of crests begin to break into spindrift. The foam is blown in well-marked streaks along the direction of the wind	37	18.9	34 to 40	17.2 to 20.7	Gale	High	5.5 (7.5)

*These columns are a guide to show roughly what may be expected in the open sea, remote from land. Figures in brackets indicate the probable maximum height of waves. In enclosed waters, or when near land with an offshore wind, wave heights will be smaller and the waves steeper.

Force	Description	Specification for use at sea*	Equivalent speed at 10 metres above sea level				Description in forecast	State of sea	Probable height of waves* /metres
			Mean		Limits				
			/knots	/ms^{-1}	/knots	/ms^{-1}			
9	Strong gale	High waves. Dense streaks of foam along the direction of the wind. Crests of waves begin to topple, tumble and roll over. Spray may affect visibility	44	22.6	41 to 47	20.8 to 24.4	Severe gale	Very high	7.0 (10.0)
10	Storm	Very high waves with long over-hanging crests. The resulting foam, in great patches, is blown in dense white streaks along the direction of the wind. On the whole the surface of the sea takes on a white appearance. The 'tumbling' of the sea becomes heavy and shock-like. Visibility affected	52	26.4	48 to 55	24.5 to 28.4	Storm	Very high	9.0 (12.5)
11	Violent storm	Exceptionally high waves (small and medium-sized ships might be for a time lost behind the waves). The sea is completely covered with long white patches of foam lying along the direction of the wind. Everywhere the edges of the wave crests are blown into froth. Visibility affected	60	30.5	56 to 63	28.5 to 32.6	Violent storm	Phenomenal	11.5 (16.0)
12	Hurricane	The air is filled with foam and spray. Sea completely white with driving spray; visibility very seriously affected	-	-	64 and over	32.7 and over	Hurricane force	Phenomenal	14.0 (-)

*These columns are a guide to show roughly what may be expected in the open sea, remote from land. Figures in brackets indicate the probable maximum height of waves. In enclosed waters, or when near land with an offshore wind, wave heights will be smaller and the waves steeper.

Table 4. Beaufort scale: specifications and equivalent speeds.

Sea states based on the Beaufort Scale

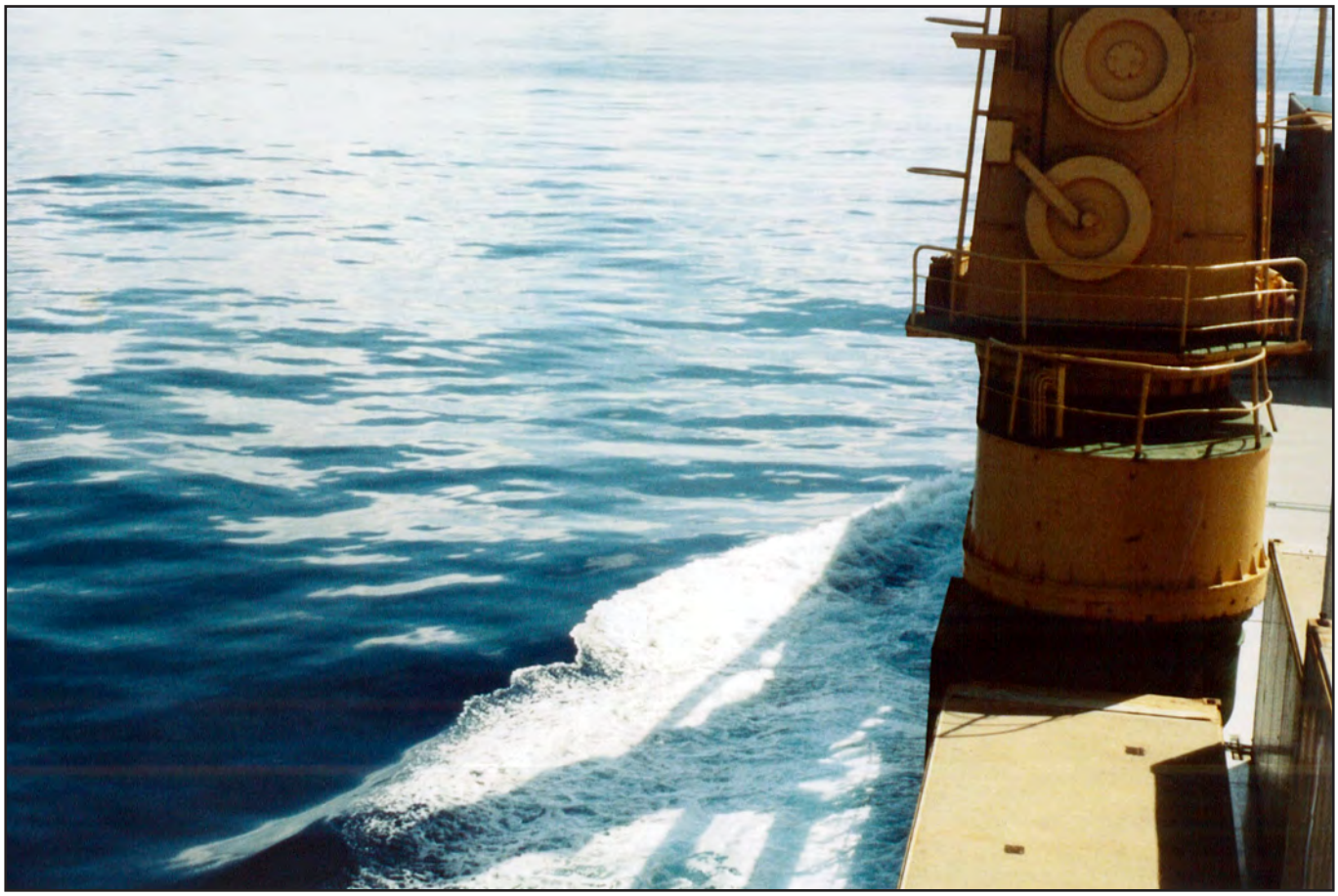


Figure 5. Sea appearance in winds of Force 0 (© N.C. Horner)

Figure 6. Sea appearance in winds of Force 1 (© G.J. Simpson)

Sea states based on the Beaufort Scale

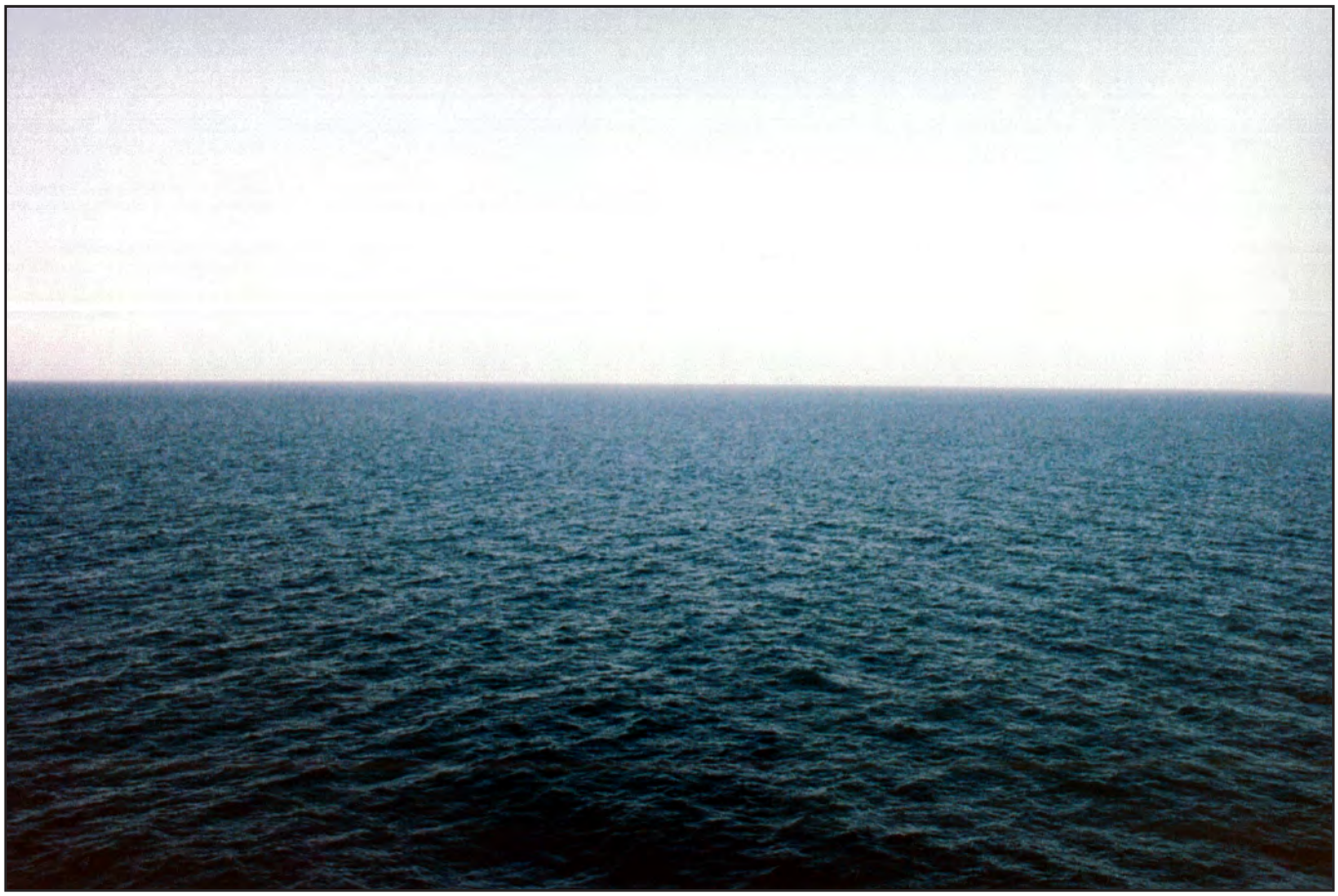


Figure 7. Sea appearance in winds of Force 2 (© G.J. Simpson)

Figure 8. Sea appearance in winds of Force 3 (© I.G. McNeil)

Sea states based on the Beaufort Scale

Figure 9. Sea appearance in winds of Force 4 (© I.G. McNeil)

Figure 10. Sea appearance in winds of Force 5 (© I.G. McNeil)

Sea states based on the Beaufort Scale

Figure 11. Sea appearance in winds of Force 6 (© I.G. McNeil)

Figure 12. Sea appearance in winds of Force 7 (© G.J. Simpson)

Sea states based on the Beaufort Scale

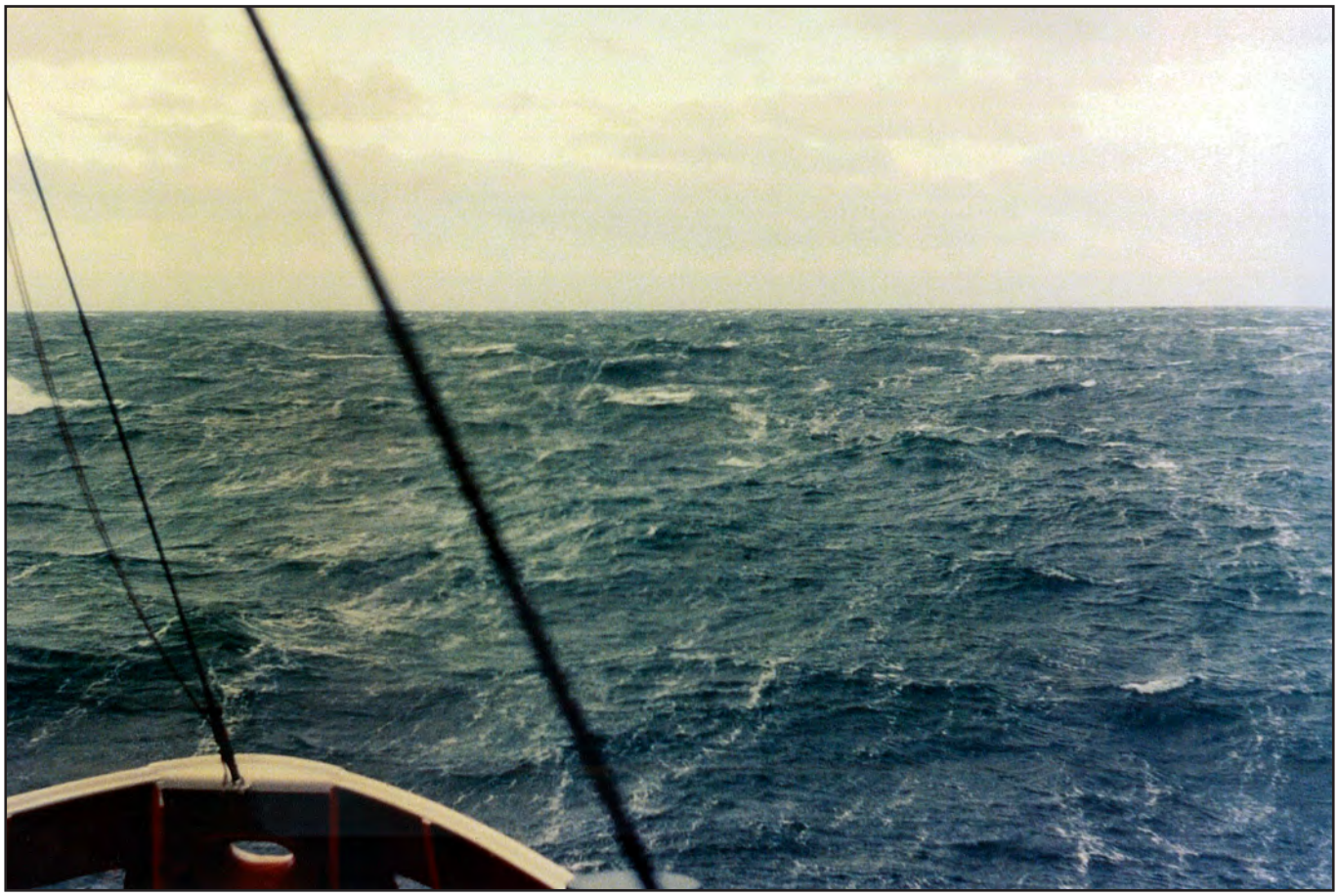


Figure 13. Sea appearance in winds of Force 8 (© W.A.E. Smith)

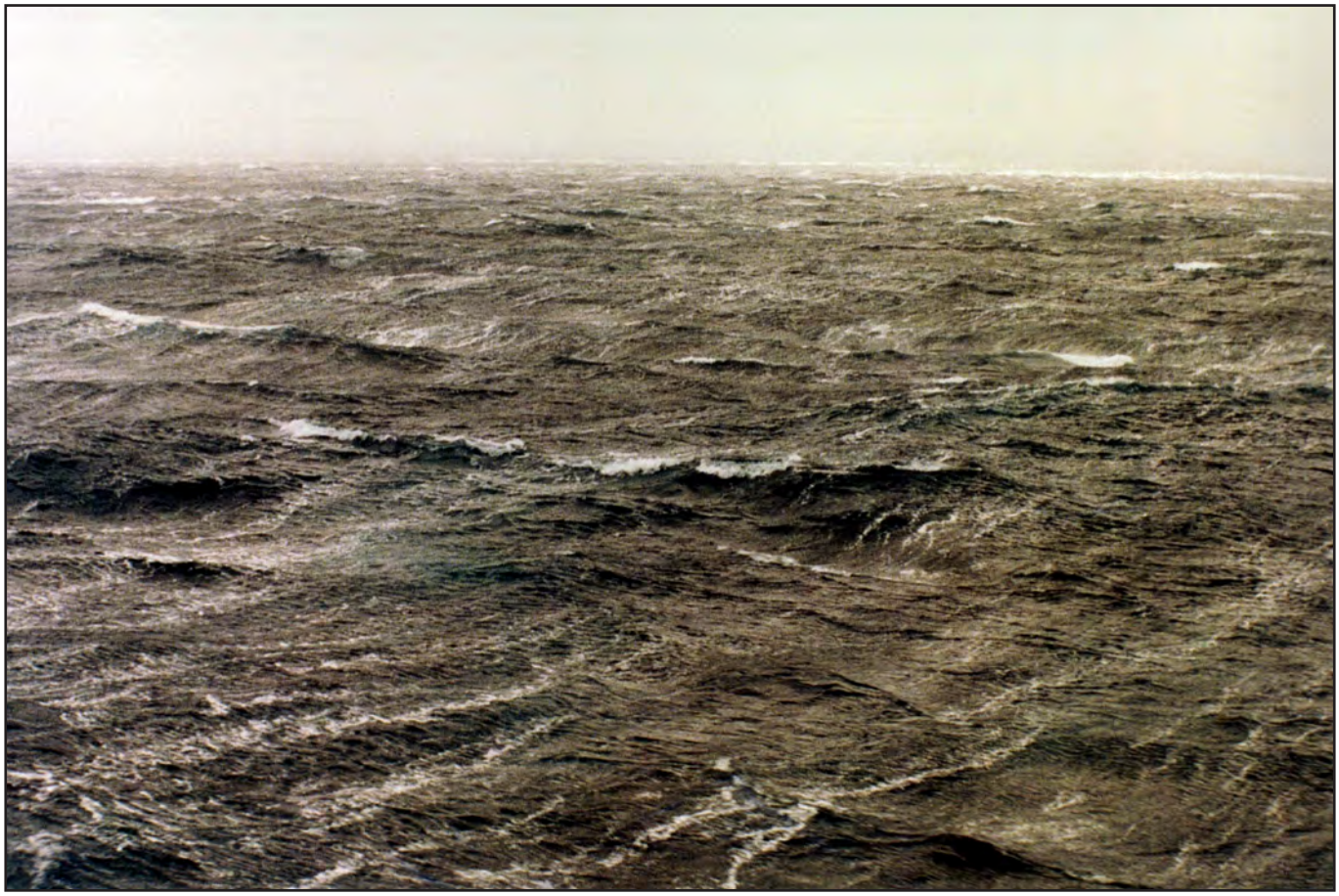


Figure 14. Sea appearance in winds of Force 9 (© J.P. Lacock)

Sea states based on the Beaufort Scale

Figure 15. Sea appearance in winds of Force 10 (© G. Allen)

Figure 16. Sea appearance in winds of Force 11 (© Crown)

Sea states based on the Beaufort Scale

Figure 17. Sea appearance in winds of Force 12 (© J.F. Thompson)

Douglas sea and swell scale

Devised in the 1920s by Captain H.P. Douglas CMG, RN, Hydrographer of the Royal Navy, for estimating the roughness of the sea for navigation and recommended for international use in 1929, this scale consists of pairs of digits, each on a scale from 0 to 9, the first representing 'sea' and the second 'swell'.

State of the sea			Swell	
Code figure	Height (m)	Description	Code figure	Description
0	0	Calm (glassy)	0	No swell
1	0 – 0.1	Calm (rippled)	1	Very low (short and low wave)
2	0.1 – 0.5	Smooth (wavelets)	2	Low (long and low wave)
3	0.5 – 1.25	Slight	3	Light (short and moderate wave)
4	1.25 – 2.5	Moderate	4	Moderate (average and moderate wave)
5	2.5 – 4.0	Rough	5	Moderate rough (long and moderate wave)
6	4.0 – 6.0	Very rough	6	Rough (short and heavy wave)
7	6.0 – 9.0	High	7	High (average and heavy wave)
8	9.0 – 14.0	Very high	8	Very high (long and heavy wave)
9	Over 14.0	Phenomenal	9	Confused (wave length and height indefinable)

Table 5. Douglas sea and swell scale.

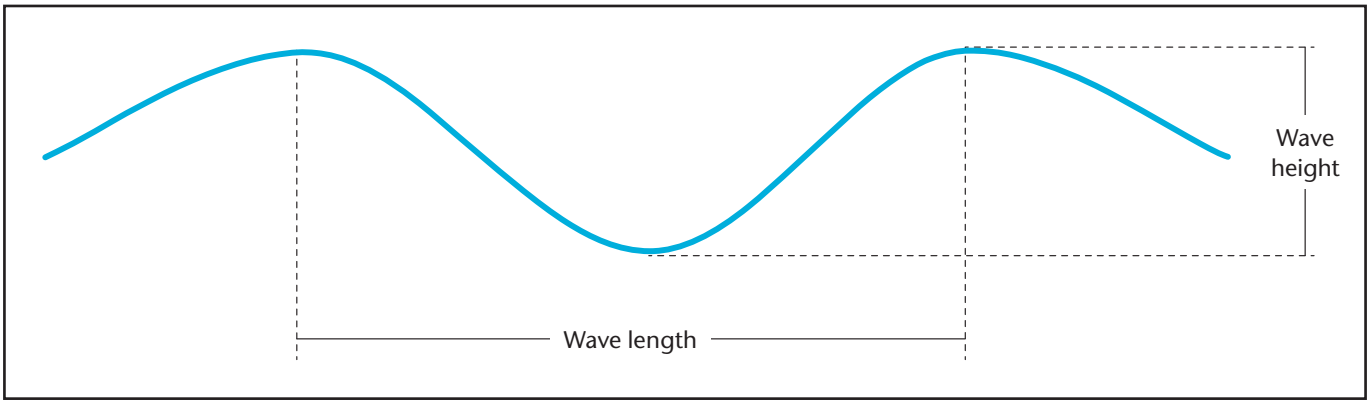
Classification

Wave length

Short wave – wave length: < 100 m
Average wave – wave length: 100 m to 200 m
Long wave – wave length: > 200 m

Wave height

Low wave – wave height: < 2 m
Moderate wave – wave height: 2 m to 4 m
High wave – wave height: > 4.0 m



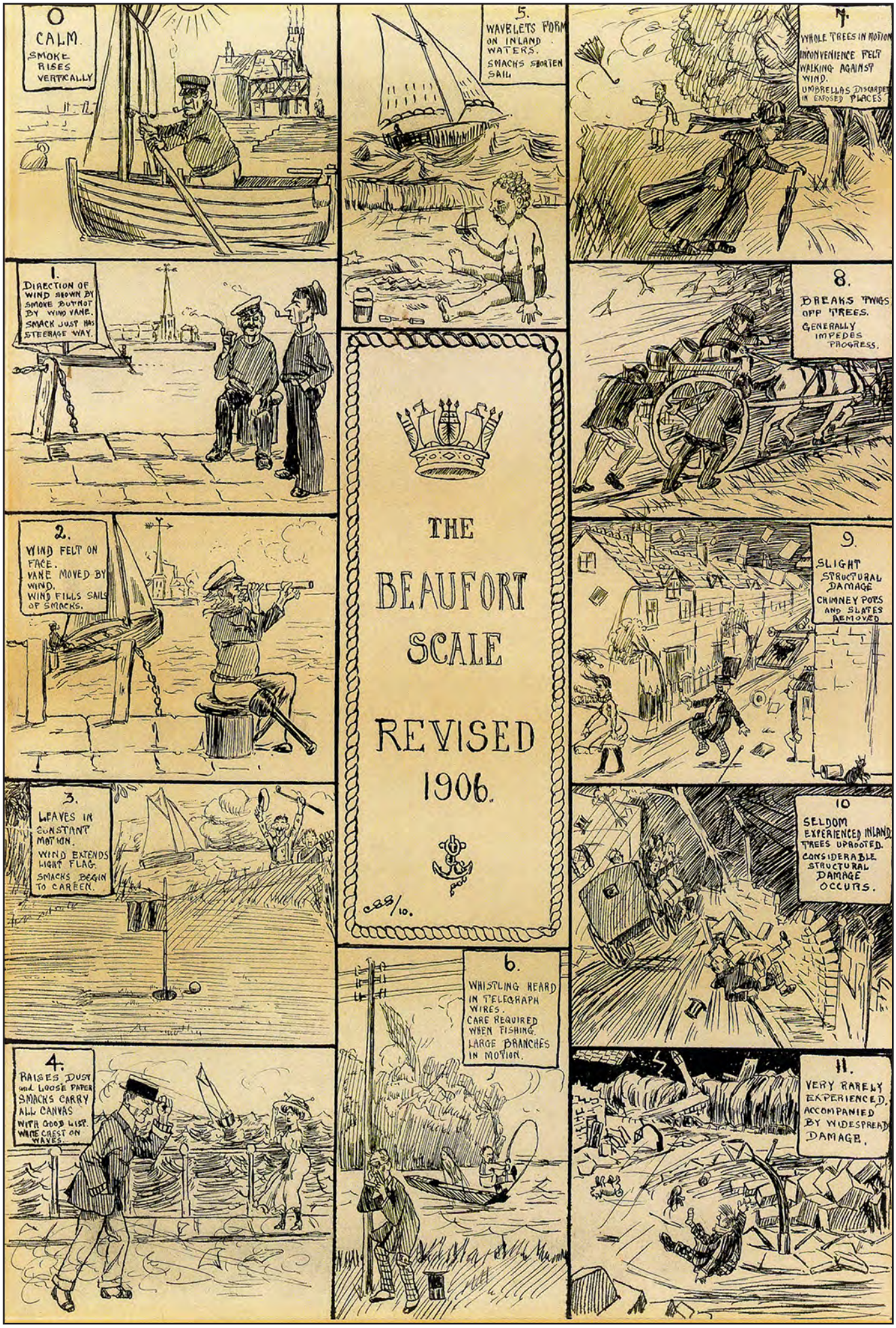
Observations on land

George Simpson devised a scale for land-based observers in 1906. Similar in concept to the scale used by the Palatine Meteorological Society, it has subsequently been altered very little.

Soon after its introduction, Simpson's version of the Beaufort scale was illustrated in a humorous but effective way.

The scale for observers on land is a useful and reasonably accurate tool for estimating wind strength. The scale for seafarers, however, is no more than 'a guide to show roughly what may be expected on the open sea, remote from land' – to quote from the warning that used to be attached to the copies of the scale issued to marine observers.

Figure 18. Simpson's scale cartoon (right)


0
CALM.
SMOKE RISES VERTICALLY
1.
DIRECTION OF WIND SHOWN BY SMOKE BUT NOT BY WIND VANE.
SMACK JUST HAS STEERAGE WAY.
2.
WIND FELT ON FACE.
VANE MOVED BY WIND.
WIND FILLS SAILS OF SMACKS.
3.
LEAVES IN CONSTANT MOTION.
WIND EXTENDS LIGHT FLAG.
SMACKS BEGIN TO CAREEN.
4.
RAISES DUST and LOOSE PAPER
SMACKS CARRY ALL CANVAS
WITH GOOD LIST.
WHITE CREST ON WAVES.
5.
WAVELETS FORM ON INLAND WATERS.
SMACKS SHORTEN SAIL
6.
WHISTLING HEARD IN TELEGRAPH WIRES.
CARE REQUIRED WHEN FISHING.
LARGE BRANCHES IN MOTION.
THE
BEAUFORT
SCALE
REVISED
1906.
CBS/10.
7.
WHOLE TREES IN MOTION
INCONVENIENCE FELT WALKING AGAINST WIND.
UMBRELLAS DISCARDED IN EXPOSED PLACES.
8.
BREAKS TWIGS OFF TREES.
GENERALLY IMPEDES PROGRESS.
9.
SLIGHT STRUCTURAL DAMAGE
CHIMNEY POTS AND SLATES REMOVED
10
SELDOM EXPERIENCED INLAND.
TREES UPROOTED.
CONSIDERABLE STRUCTURAL DAMAGE OCCURS.
11.
VERY RARELY EXPERIENCED.
ACCOMPANIED BY WIDESPREAD DAMAGE.

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