Deep Ocean Wind Waves

Ch. 1 Waves, Tides and Shallow-Water Processes*: J. Wright, A. Colling, & D. Park: Butterworth-Heinemann, Oxford UK, 1999, 2nd Edition, 227 pp.*

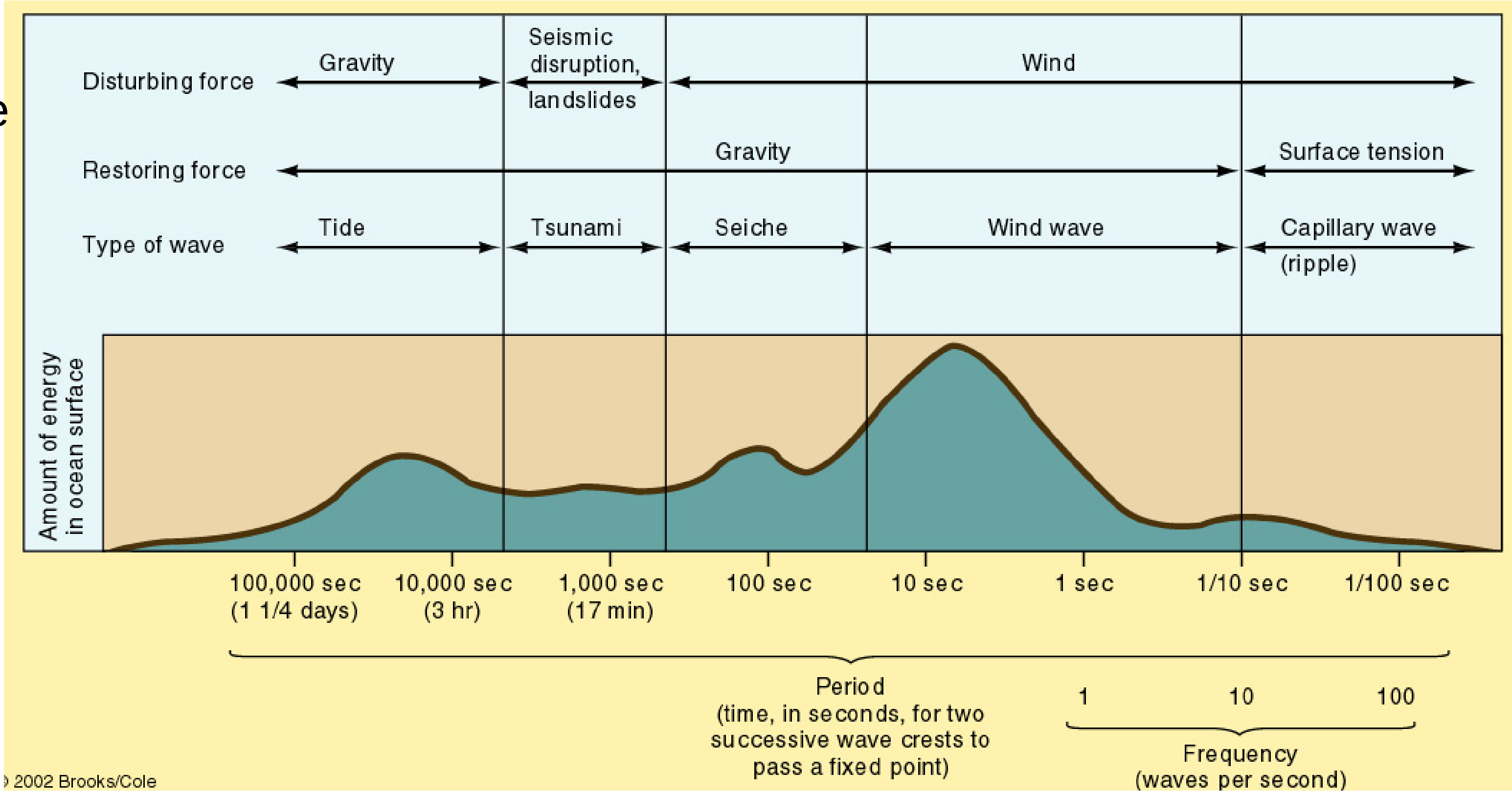
AdOc 4060/5060 Spring 2013

Types of Waves

Classifiers

- Disturbing force
- Restoring force
- Type of wave

- Wavelength
- Period
- Frequency



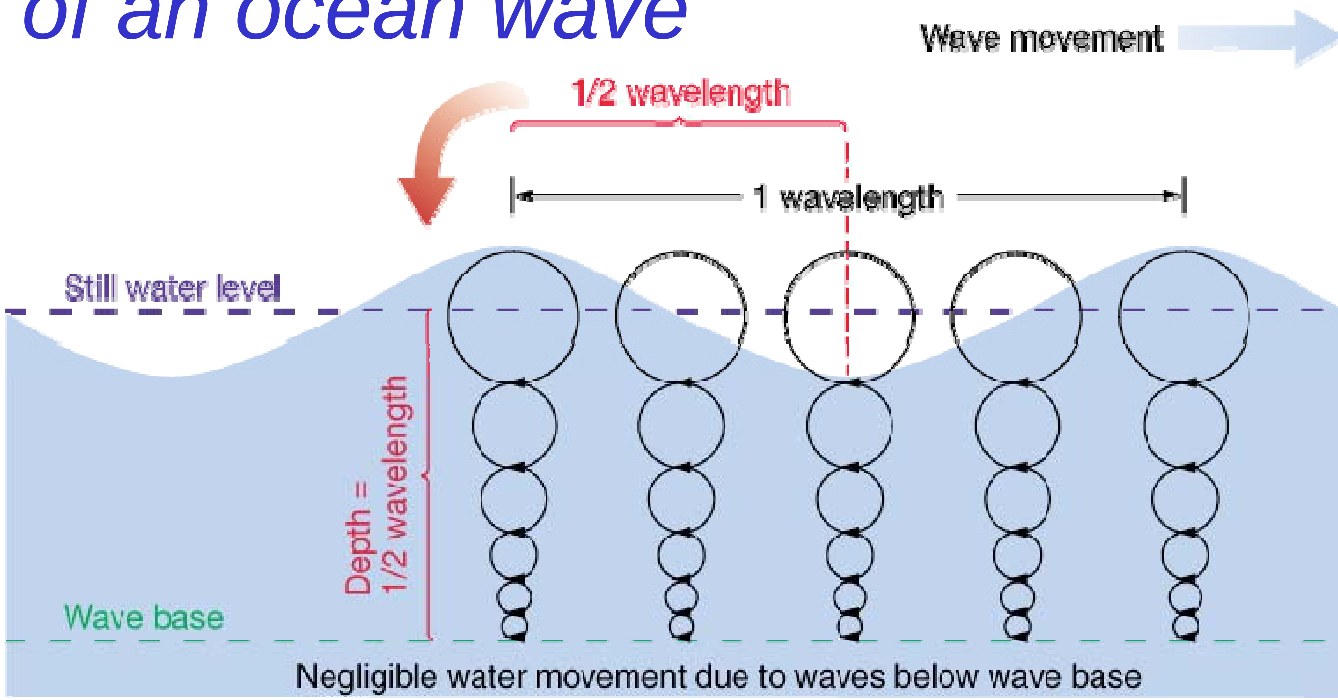
- Waves transmit energy, not mass, across ocean surfaces.
- Wave behavior depends on a wave’s size and water depth.
- Wind waves: energy is transferred from wind to water.
- Waves can change direction by refraction and diffraction, can interfere with one another, & reflect from solid objects.

- **Orbital waves** are a type of **progressive wave**: i.e. waves of moving energy traveling in one direction along a surface, where particles of water move in closed circles as the wave passes.

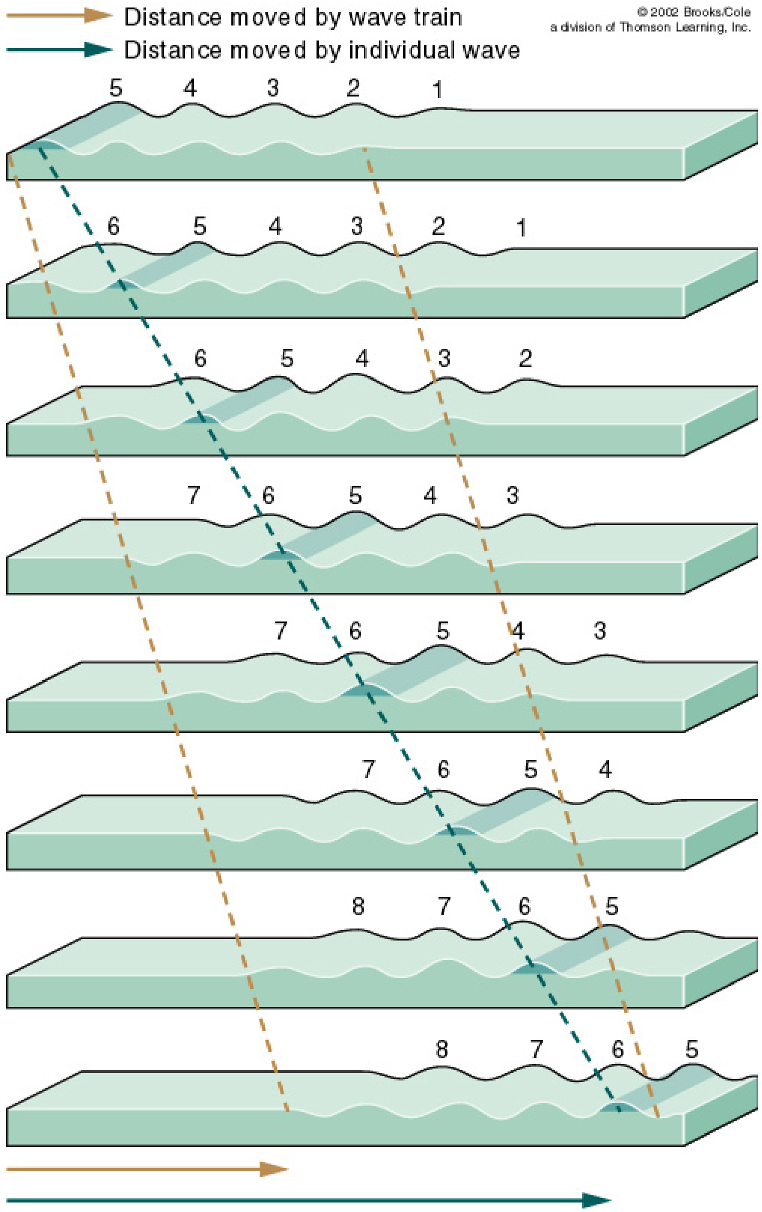
- **Free waves** move independently of the generating force: wind waves. In **forced waves** the disturbing force is applied continuously: tides

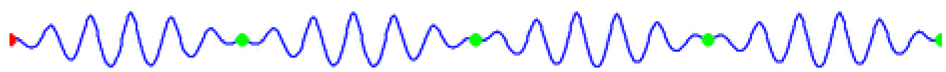
Parts of an ocean wave

- Crest
- Trough
- Wave height (*H*)
- Wavelength (*L*)
- Wave speed (*c*)
- Still water level
- Orbital motion
- Frequency $f = 1/T$
- Period $T=L/c$
- Depth of wave base = ½*L*, from still water
- Wave steepness =H/L
- If wave steepness $>{}^{1}/_{7}$, the wave breaks



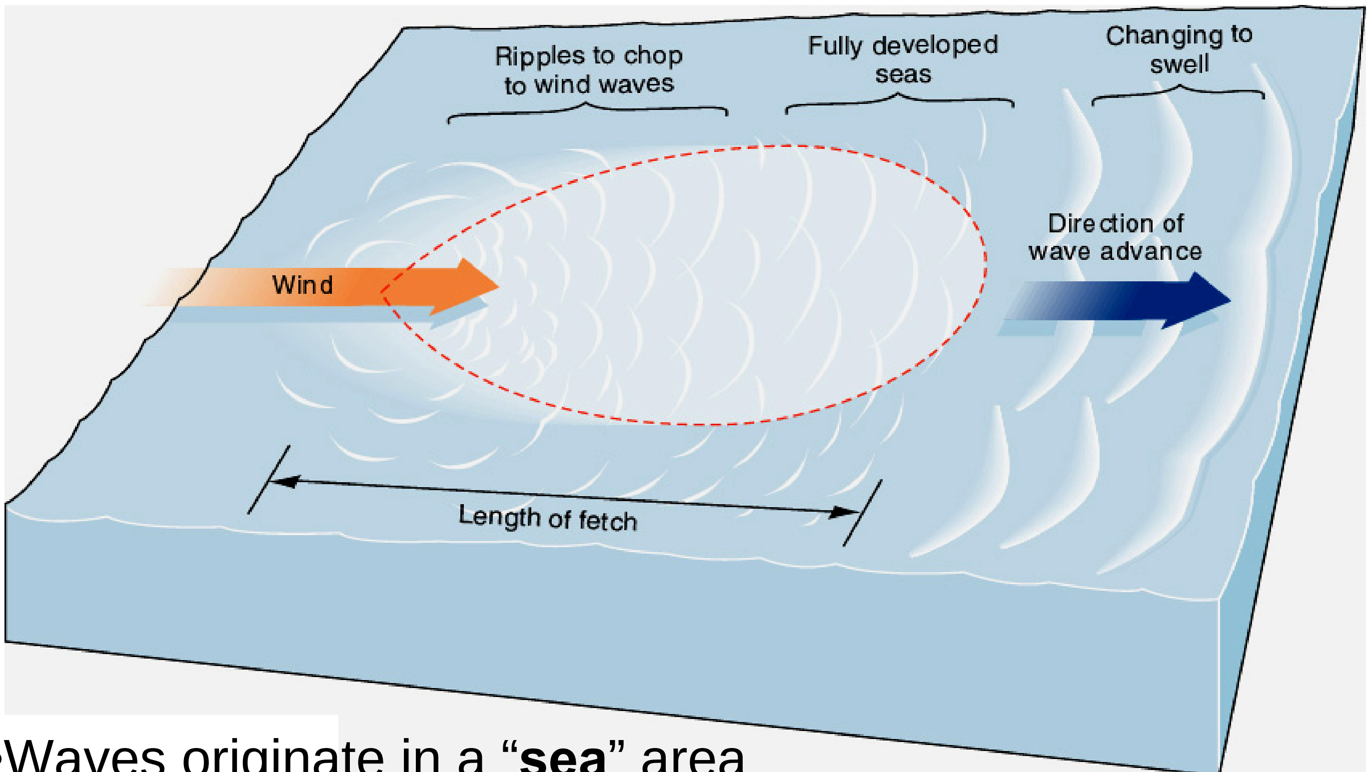
Water molecules in the crest of the wave move in the same direction as the wave, but molecules in the trough move in the opposite direction.





Group Velocity against Phase Velocity = $C_g << C_p$

Factors Affecting Wind Wave Development



- Waves originate in a “**sea**” area
- A **fully developed sea** is the maximum height of waves produced by conditions of wind speed, duration, and fetch
- **Swell** are waves that have traveled out of the fetch area and exhibit a uniform and symmetrical shape

Factors affecting wind wave development

Wind strength - wind speed must be faster than the wave crests for energy transfer to continue

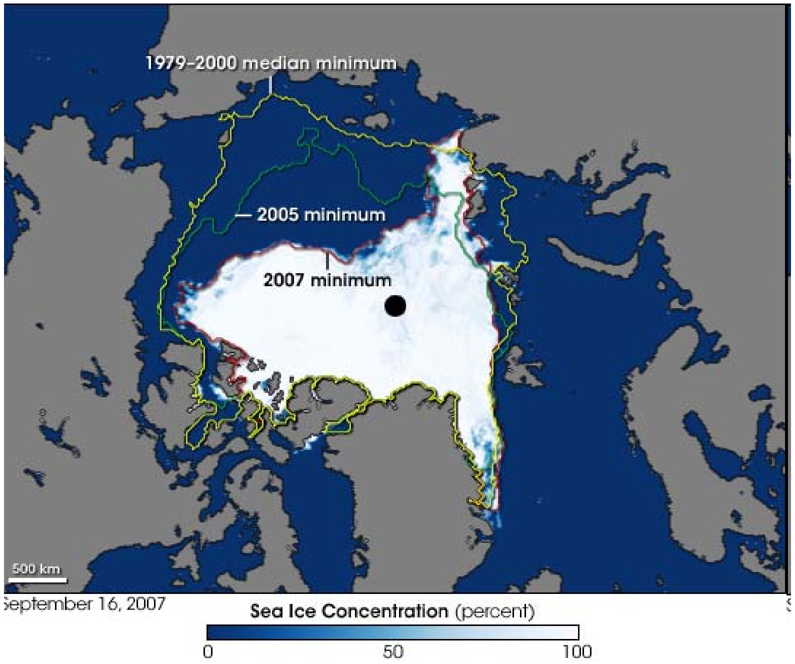
Wind duration - winds that blow for a short time will not generate large waves

Fetch - the uninterrupted distance over which the wind blows without changing direction

Swells - travel faster than the wind, outside the "sea"

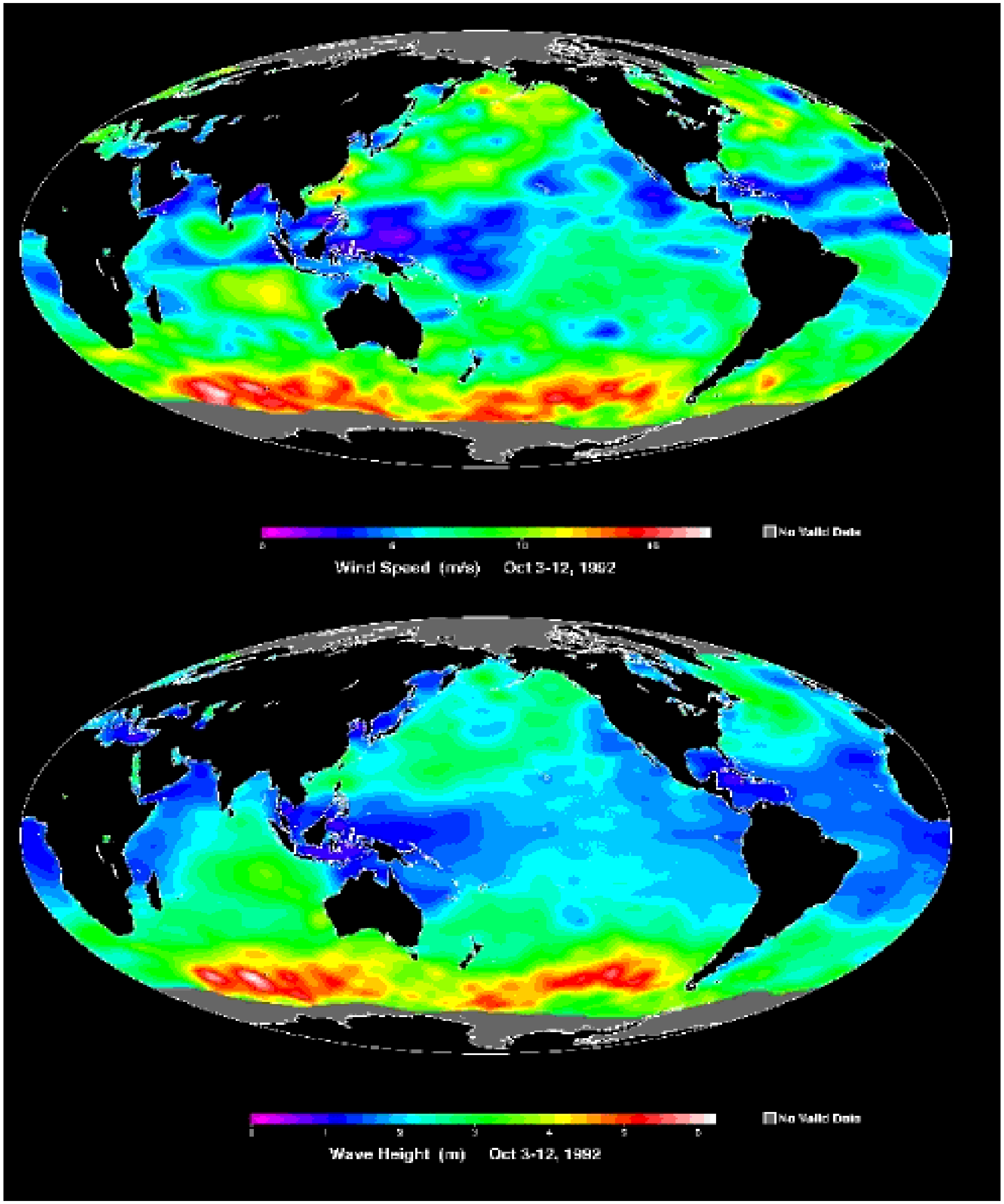
- lose little energy while traveling over the ocean surface
- swells from Antarctic storms have been recorded breaking on the Alaskan coast after traveling 10,000 km

Arctic fetch is changing, a factor in severe coastal erosion



Beaufort Wind Scale

Beaufort Force	Windspeed Knots	Description	Sea Condition
0	0	Calm	Sea like a mirror
1	1 - 3	Light Air	Ripples but without foam crests
2	4 - 6	Light Breeze	Small wavelets. Crests do not break
3	7 - 10	Gentle Breeze	Large wavelets. Perhaps scattered white horses
4	11 - 16	Moderate Breeze	Small waves. Fairly frequent white horses.
5	17 - 21	Fresh Breeze	Moderate waves, many white horses
6	22 - 27	Strong Breeze	Large waves begin to form; white foam crests, probably spray
7	28 - 33	Near Gale	Sea heaps up and white foam blown in streaks along the direction of the wind
8	34 - 40	Gale	Moderately high waves, crests begin to break into spindrift
9	41 - 47	Strong Gale	High waves. Dense foam along the direction of the wind. Crests of waves begin to roll over. Spray may affect visibility
10	48 - 55	Storm	Very high waves with long overhanging crests. The surface of the sea takes a white appearance. The tumbling of the sea becomes heavy and shock like. Visibility affected
11	56 - 63	Violent Storm	Exceptionally high waves. The sea is completely covered with long white patches of foam lying in the direction of the wind. Visibility affected
12	64+	Hurricane	The air is filled with foam and spray. Sea completely white with driving spray. Visibility very seriously affected.



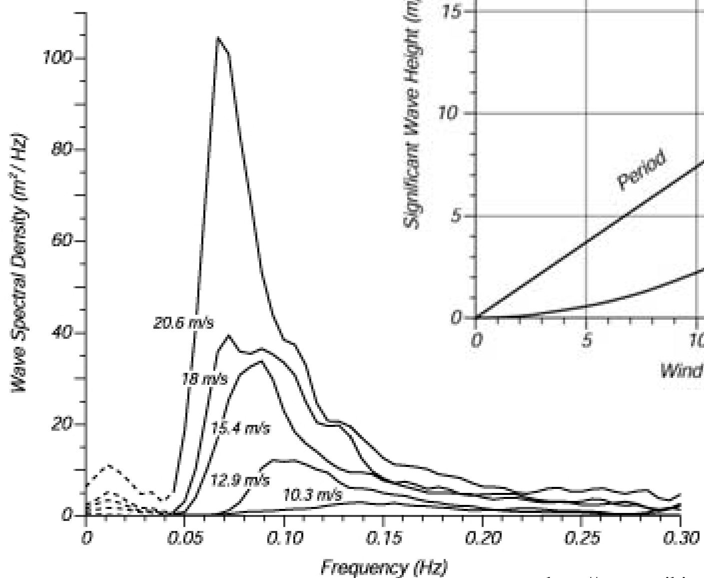
Wind speed (m/s)

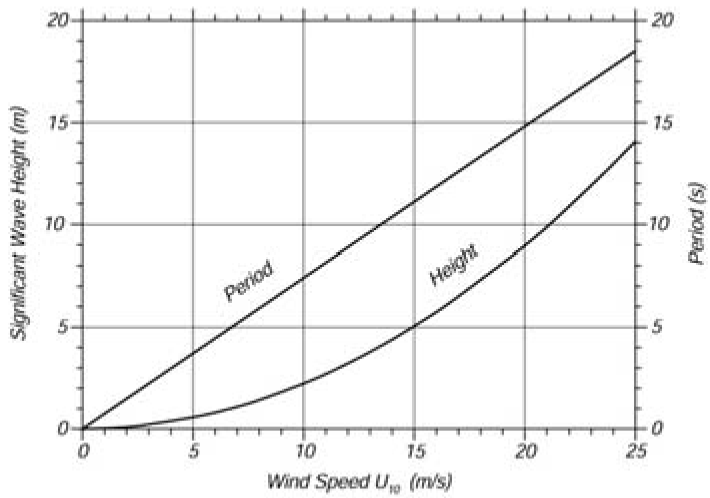
Wave height (m)

Wind Waves

- as wind-waves gain Energy, their wave steepness increases, when H = 1/7 then **open ocean breakers** form: **whitecaps**
- as the Energy continues to increase, the appearance of the sea changes, these changes are described as the **Beaufort Scale** (see Table 1.1)
- Wave-heights are measured presently by satellites and maps of the ocean surface are created weekly (daily where there are ship and buoy data available).
- on a given day, world wide there will be calm locations (often near the tropics) and high wave areas (Southern Ocean)
- the height of the highest 10% of the waves in a fully developed sea are ≈ twice the average height: called significant waves for insurance purposes

Measuring waves





http://www.wikiwaves.org/Ocean-Wave_Spectra

http://www.youtube.com/watch?v=5AGEpBjcZ4s

http://www.youtube.com/watch?v=BR24WCKrJx0

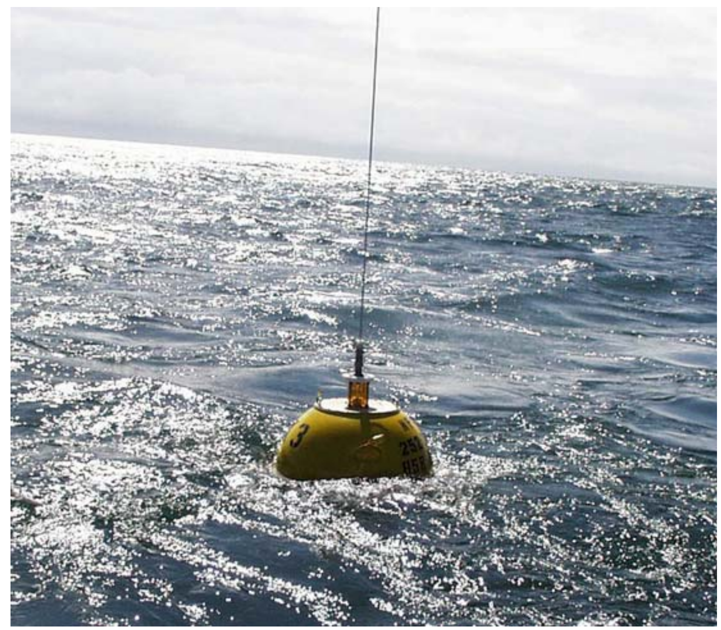


Table 8–1 Description of a fully developed sea for a given wind speed.

Wind speed in km/h (mi/h)	*Average height in m (ft)*	*Average length in m (ft)*	*Average period in sec*	*Highest 10% of waves in m (ft)*
20 (12)	0.33 (1.0)	10.6 (34.8)	3.2	0.75 (2.5)
30 (19)	0.88 (2.9)	22.2 (72.8)	4.6	2.1 (6.9)
40 (25)	1.8 (5.9)	39.7 (130.2)	6.2	3.9 (12.8)
50 (31)	3.2 (10.5)	61.8 (202.7)	7.7	6.8 (22.3)
60 (37)	5.1 (16.7)	89.2 (292.6)	9.1	10.5 (34.4)
70 (43)	7.4 (24.3)	121.4 (398.2)	10.8	15.3 (50.2)
80 (50)	10.3 (33.8)	158.6 (520.2)	12.4	21.4 (70.2)
90 (56)	13.9 (45.6)	201.6 (661.2)	13.9	28.4 (93.2)

Significant wave-height

The concept of significant wave-height **was developed during the World War II as part of a project to forecast ocean wave-heights and periods. Wiegel (1964: p. 198) reports that work at the Scripps Institution of Oceanography showed... wave-height estimated by observers corresponds to the average of the highest 20 to 40 per cent of waves... Originally, the term significant wave-height was attached to the average of these observations, the highest 30 percent of the waves, but has evolved to become the average of the highest one-third of the waves, (designated H_S or $H_{1/3}$).**

More recently, significant wave-height is calculated from measured wave displacement. If the sea contains a narrow range of wave frequencies, $H_{1/3}$ is related to the standard deviation of sea-surface displacement (NAS, 1963: 22; Hoffman and Karst, 1975)

ζ is the sea-level displacement

$$H_{1/3} = 4 < \zeta^2 >^{1/2}$$

where $< \zeta^2 >^{1/2}$ is the standard deviation of surface displacement. This relationship is much more useful, and it is now the accepted way to calculate wave-height from wave measurements.

Exceedance statistics

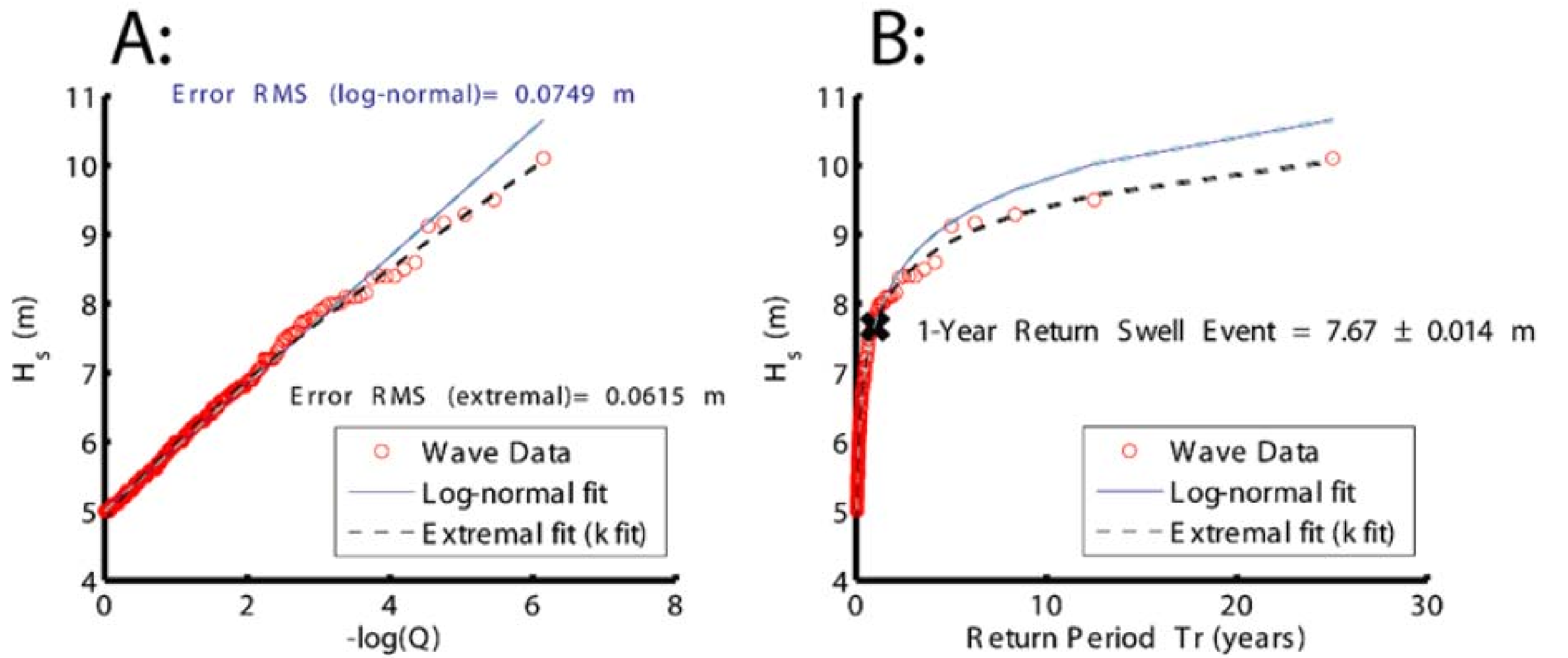
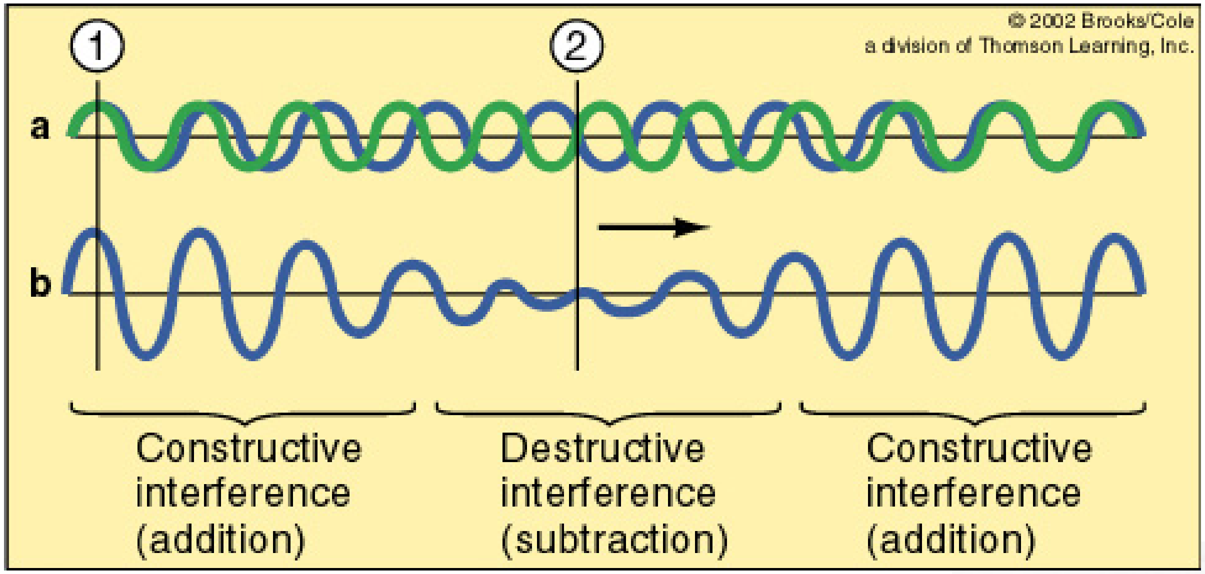
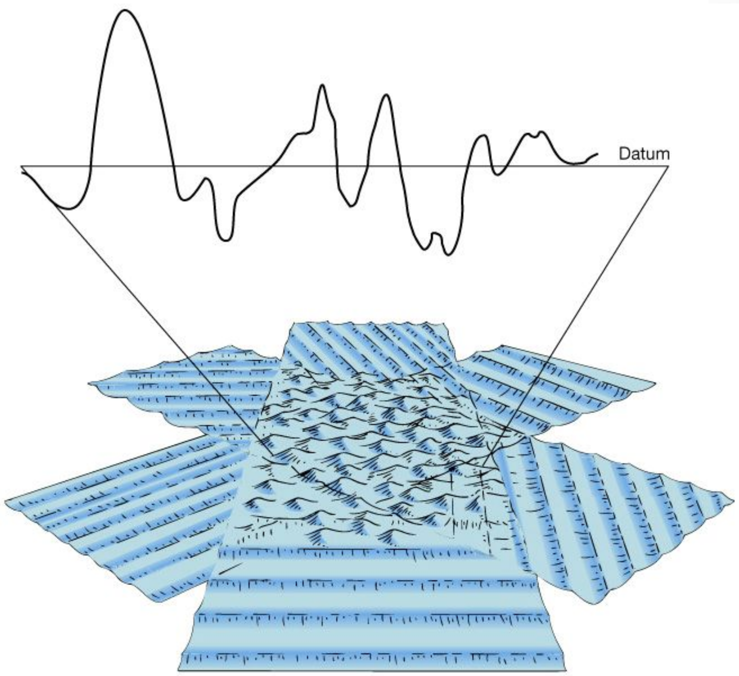


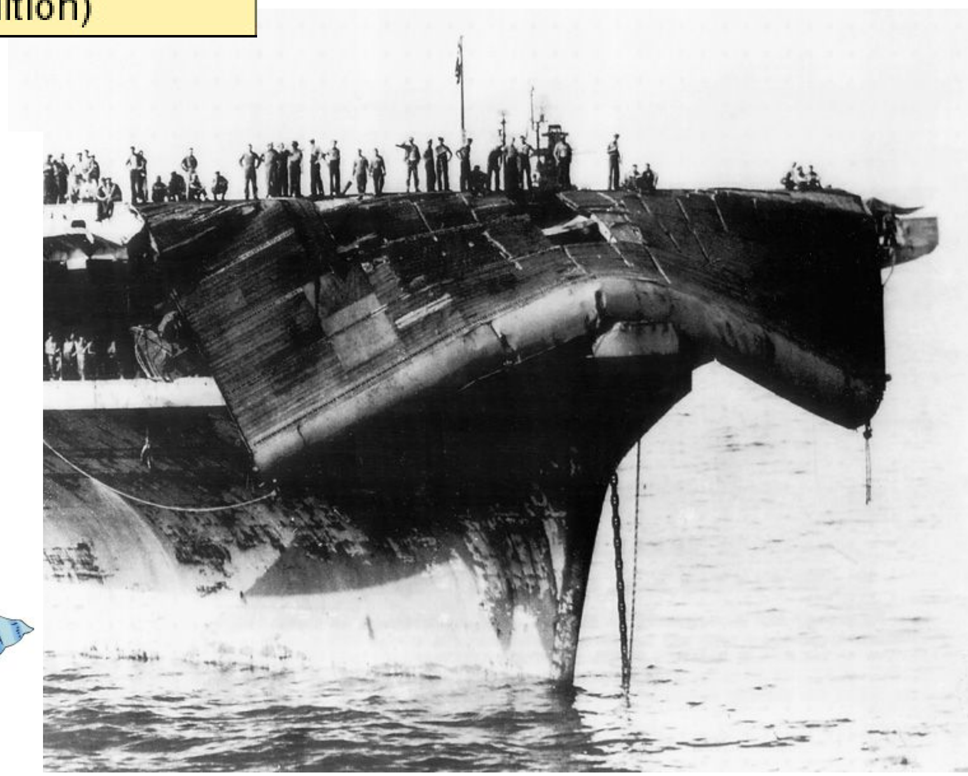
FIGURE 1. Log-normal and extremal probability models for the top 70 largest wave height events per year recorded by buoy 1. The largest wave heights recorded by buoy 1 are plotted versus the negative log of exceedance probability in (*A*) and plotted versus the return period in (*B*). In these models the largest event (a 12.3 m significant wave height) outlier has been removed and the peak over threshold method is used with a threshold of 5 m.

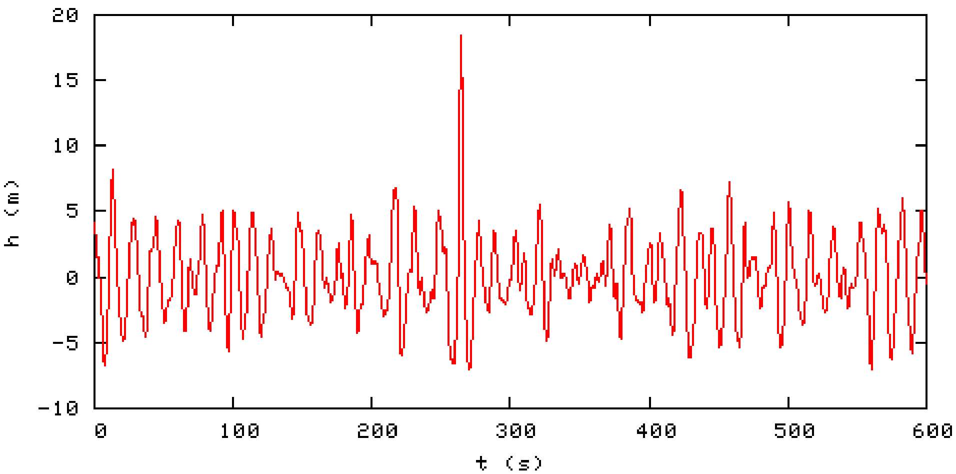
Wave Interference & Rogue Waves

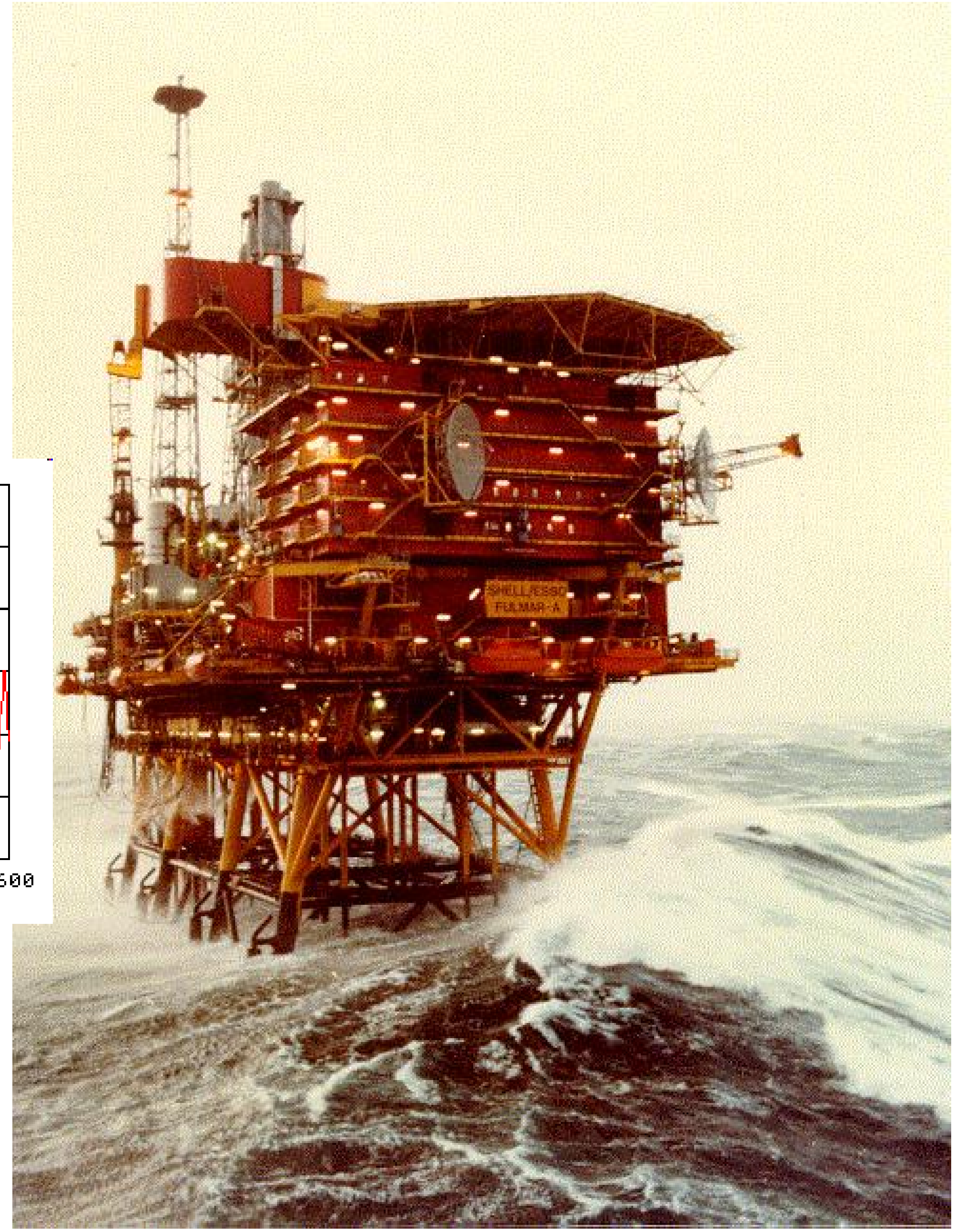


Rogue waves - these freak waves occur due to interference and result in a wave crest higher than the theoretical maximum.









First measured rogue wave (from an oil platform in the North Sea, 1995)

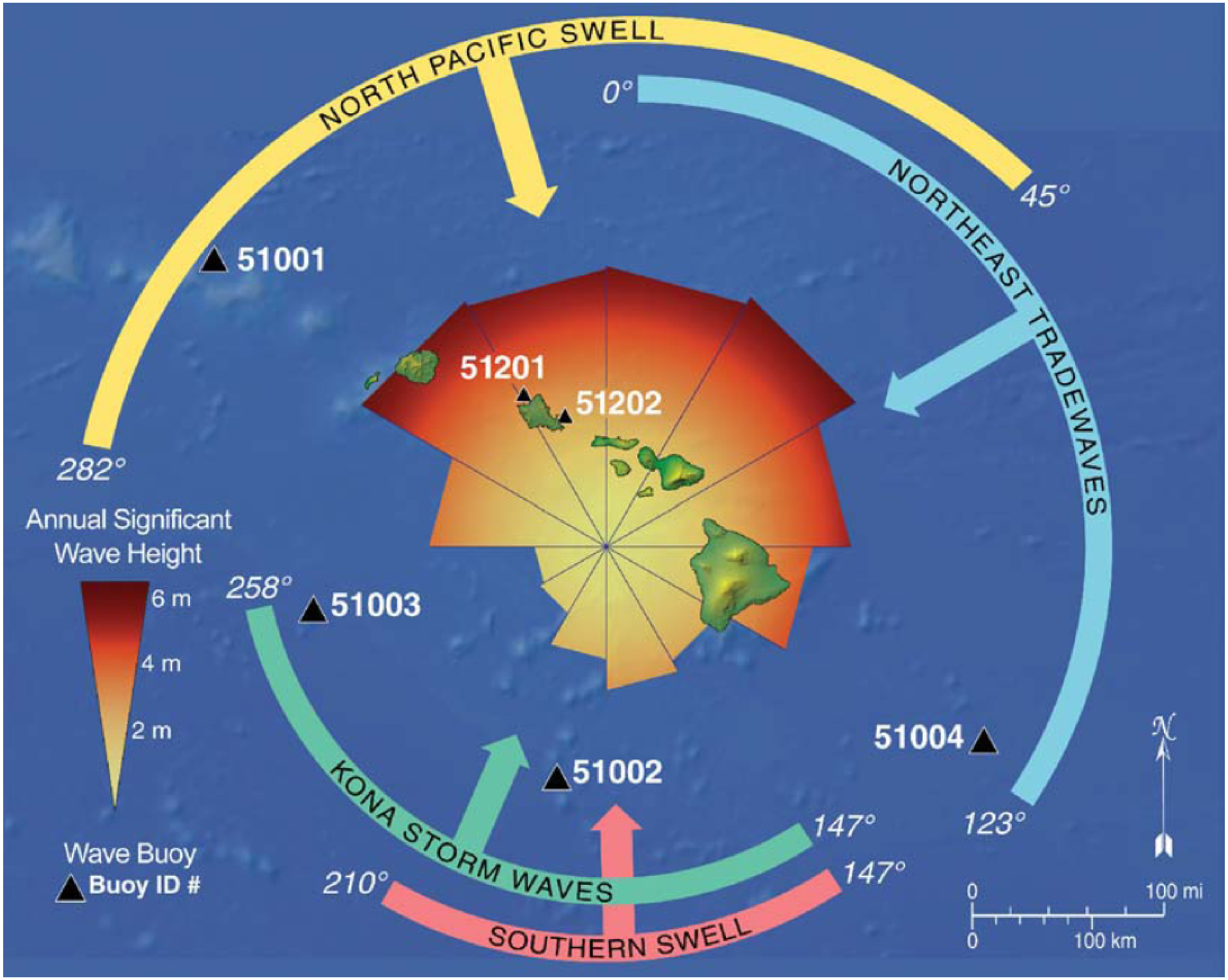


PLATE 1. Hawai'i dominant swell regimes after Moberly and Chamberlain (1964), and wave-monitoring buoy locations.