# Surface Waves and Air-Sea Fluxes

OCN/MET665
Spring 2016

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# Surface Wave and Air-Sea Fluxes

- Wave basics
- Momentum flux to wave field
- Energy balance for wave field
- Modification of momentum fluxes by waves
- Dissipation of wave energy by breaking [TKE “flux” into upper ocean]
- Modification of other turbulent fluxes by waves

# Linear Wave Dispersion Relationship

**Deep water limit**

$$\omega^2 = g\kappa + \gamma\kappa^3$$

$$\omega = \frac{2\pi}{T}, \kappa = \frac{2\pi}{L}, \gamma = \frac{\sigma}{\rho}$$

**σ is surface tension**

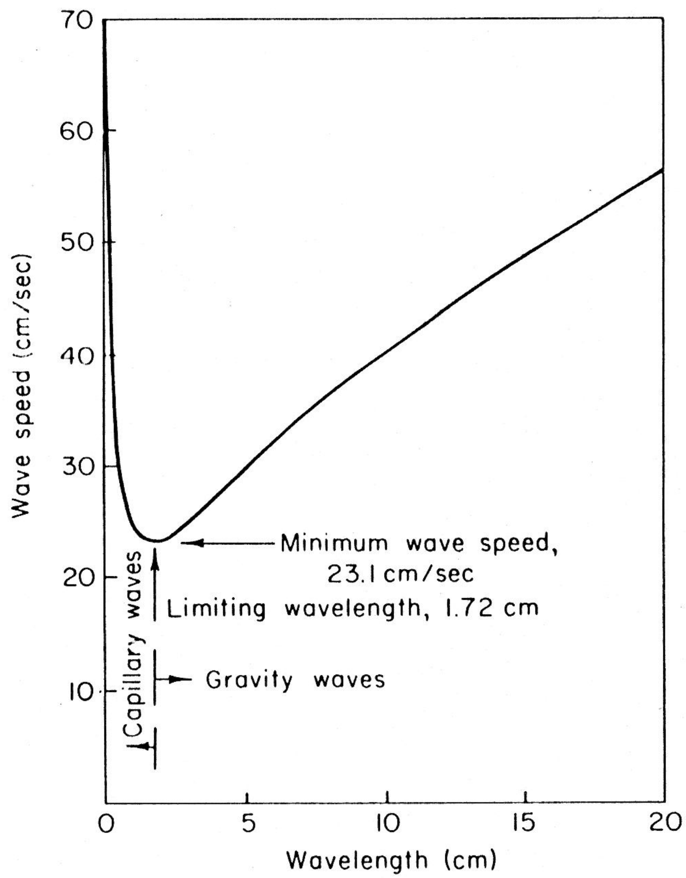



FIG. 23. Relationship between wavelength and wave speed under the action of gravity and capillarity ($\gamma = 75.3$ gm sec$^{-2}$).

$$c = \frac{\omega}{\kappa}$$ **phase velocity**

$$c_g = \frac{\partial\omega}{\partial\kappa} + \frac{\kappa\gamma}{\rho c}$$ **group velocity**

# Gravity & Capillary Waves

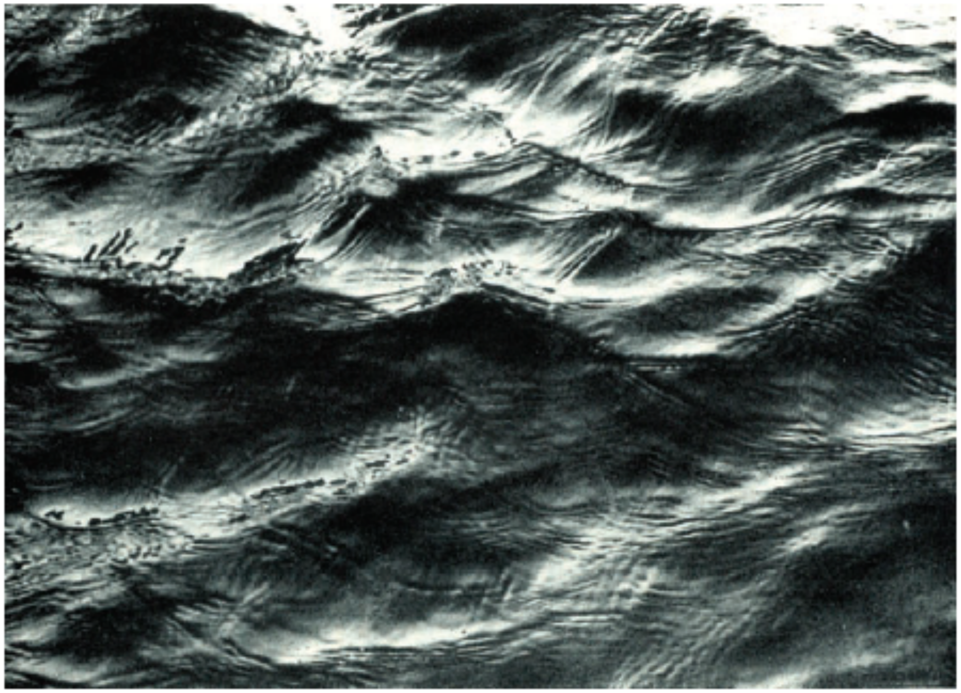


Figure 23

This photograph was taken by William van Arx off Woods Hole dock nearly fifty years ago, and was reproduced in Munk (1955). I estimate that the distance across is approximately two meters.

# Wave Growth Depends on Wind Fetch and Duration

energy transfer from wind to waves
is integrated over time and distance

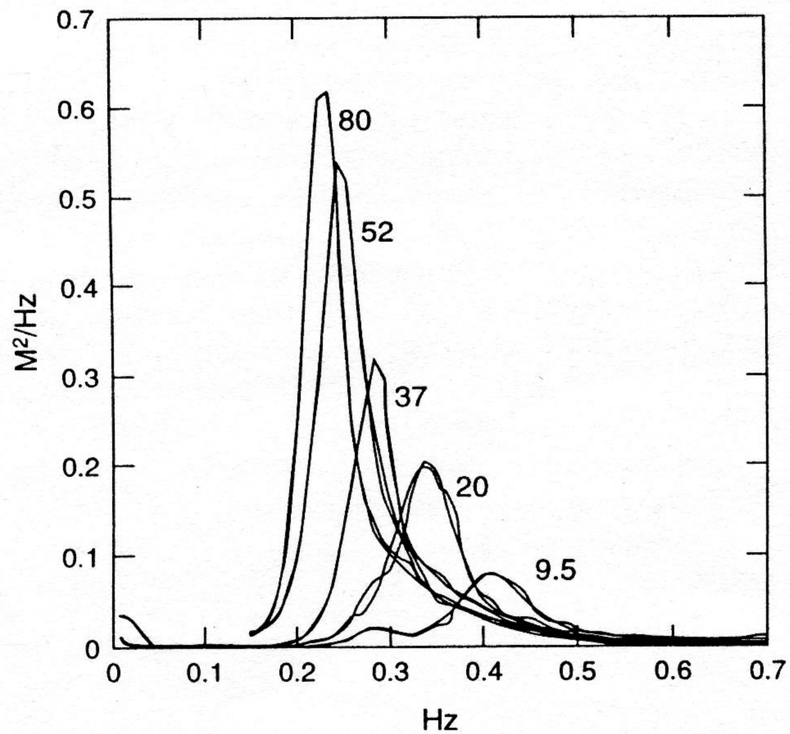
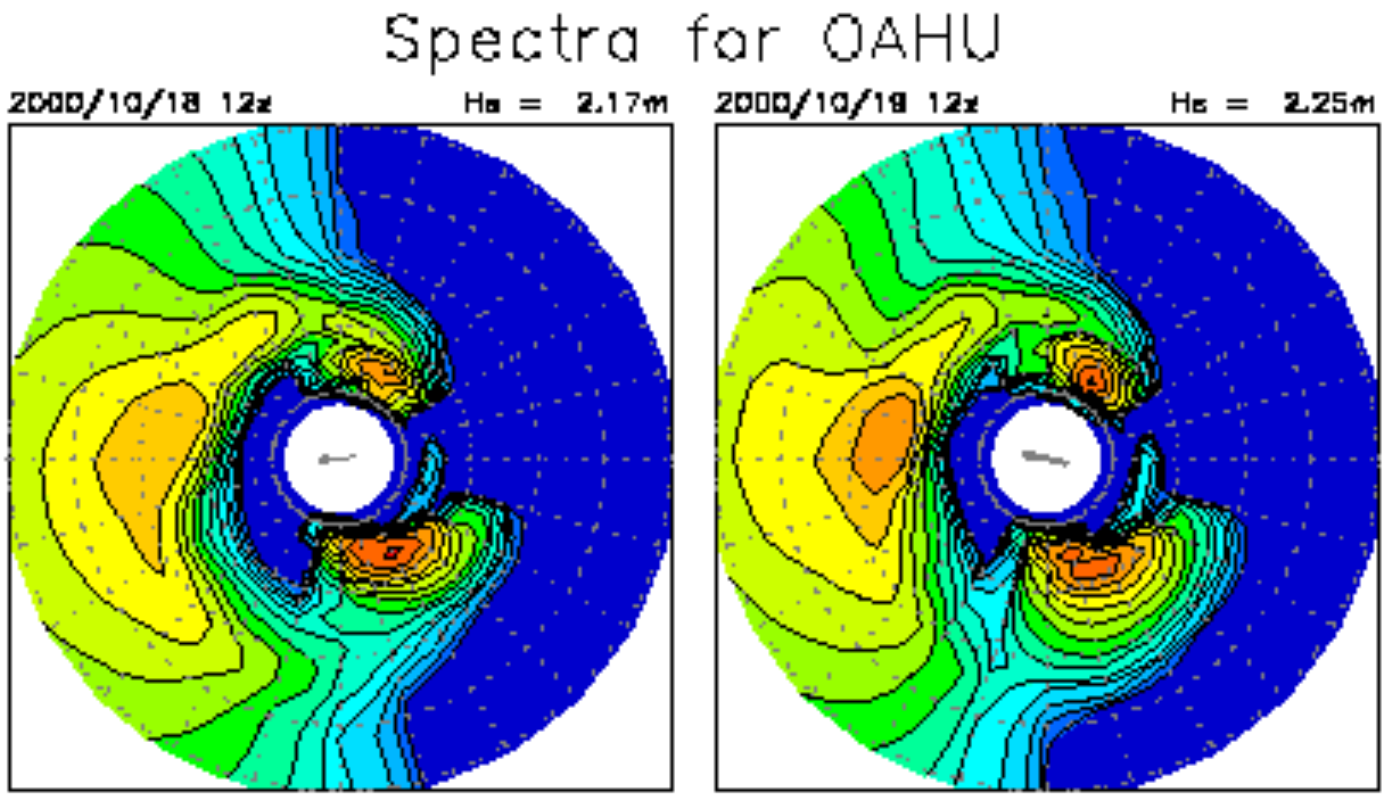



**Fig. 4.8.** Evolution of wave spectra for offshore winds ($11^h$–$12^h$, Sept. 15, 1968). The number next to the different curves indicate the fetch in kilometres. After Hasselmann et al. (1973).

# 2-dimensional wavenumber spectrum

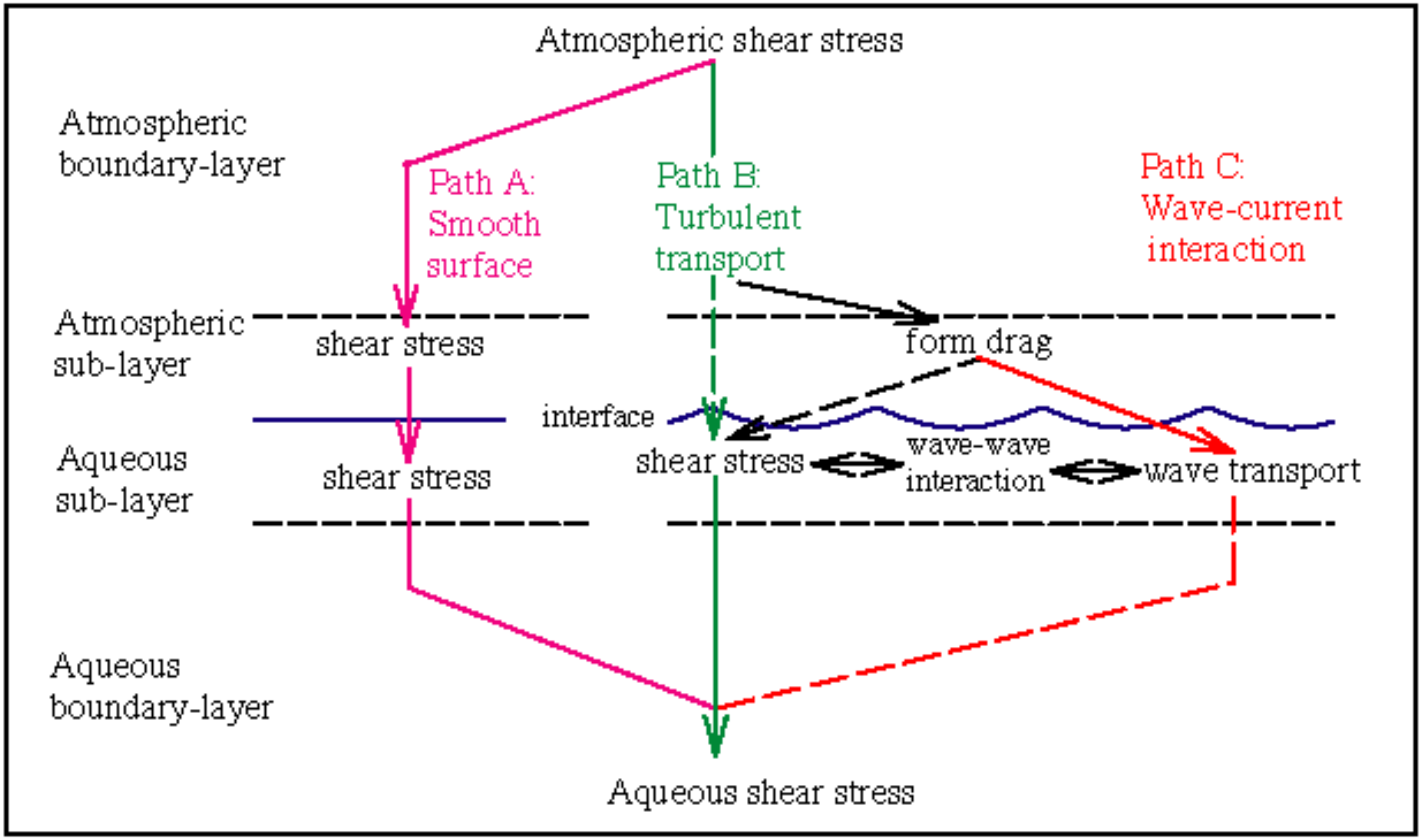
Illustrates local trade wind seas and swell +

SSW swell + NNW swell




Concentric rings are frequency values, smaller towards center

# Boundary Layer Energetics




Stewart (1961) suggested that
momentum → form drag → waves → dissipation → drift current

# Total Stress = Turbulent/Interfacial stress + Wave stress

**Wave induced stress for young seas is a significant fraction of total**

**u* = 0.7 m/s**

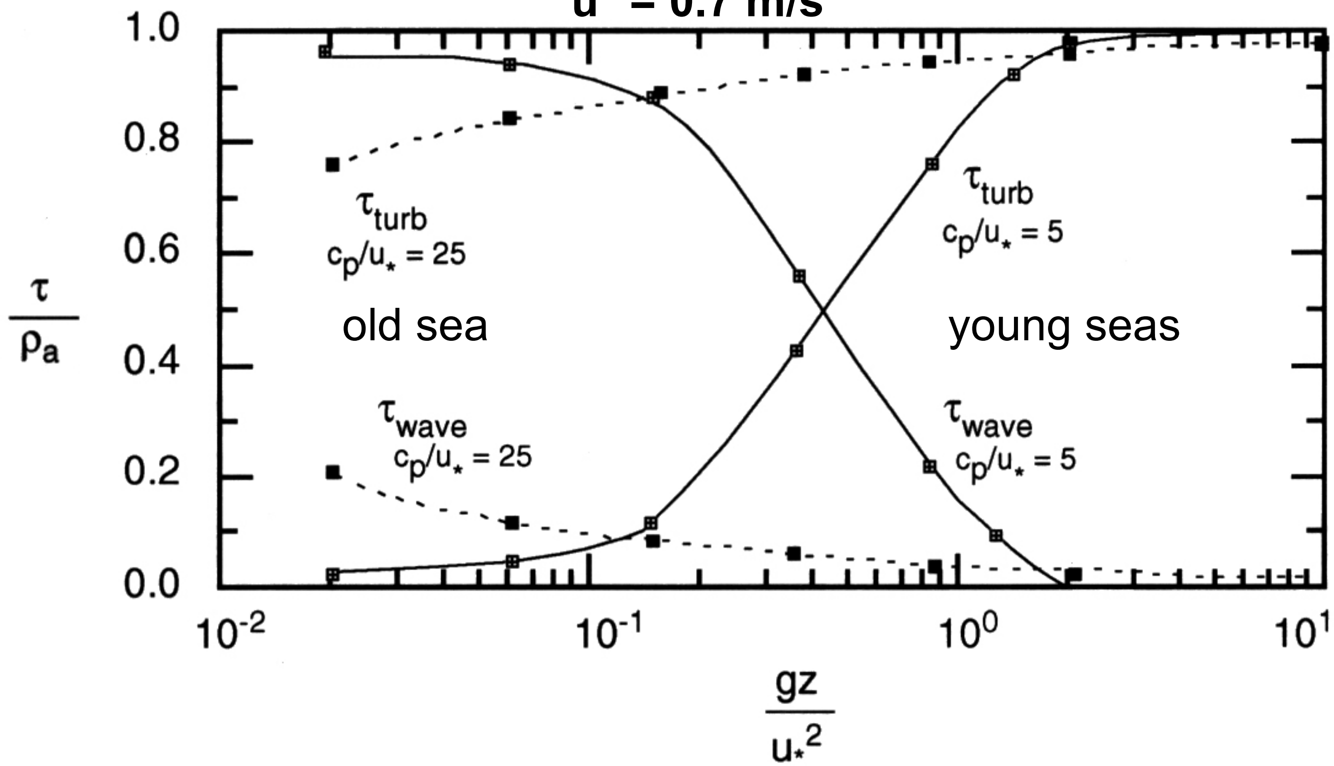
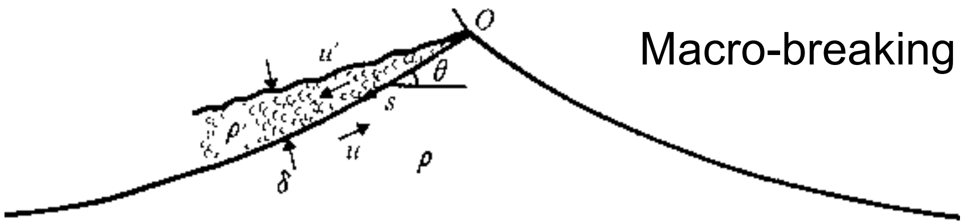



**Figure 5.7.5.** Turbulent and wave portions of the shear stress as functions of the height abo free surface for young and mature seas (from Komen *et al.*, 1994).

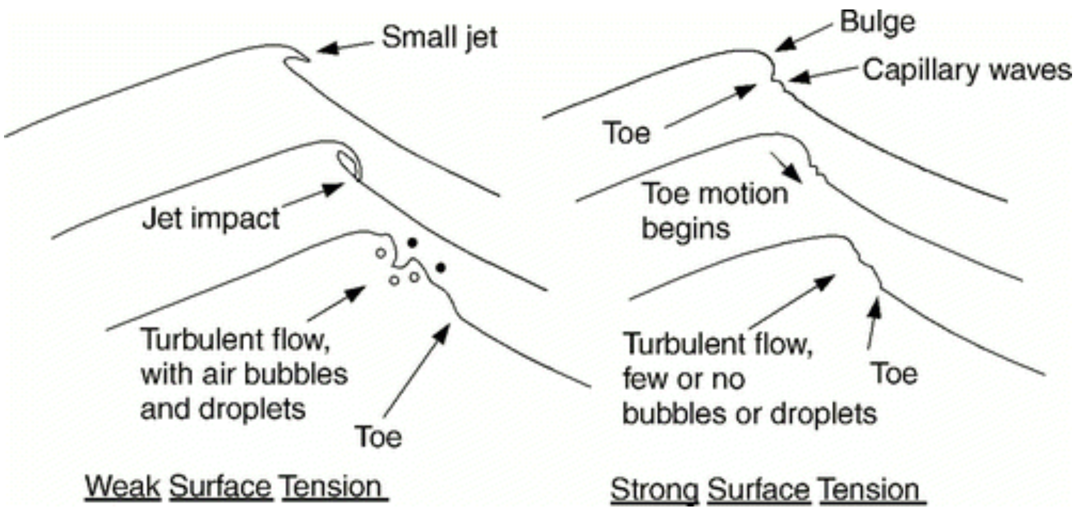
# Wave-Breaking




Macro-breaking

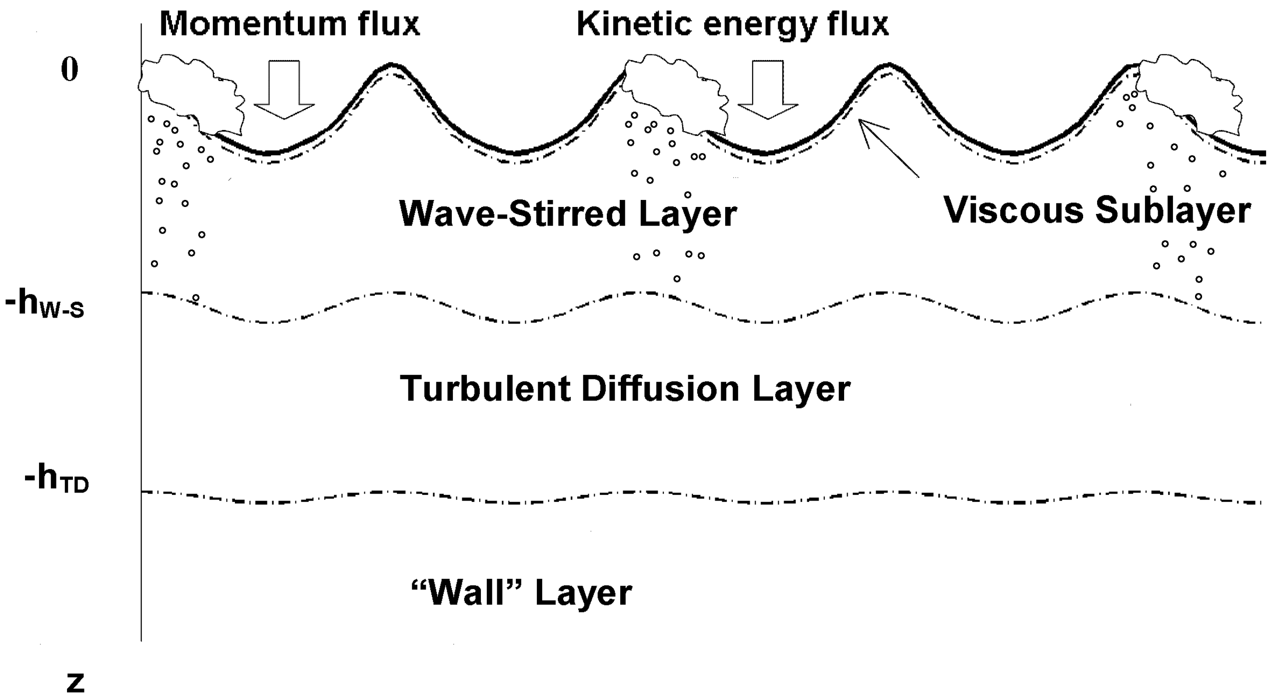
**Schematic representation of the Longuet-Higgins and Turner (1974) model of a spilling breaker. The wave is moving from right to left and has a whitecap on its forward face.**

Micro-breaking




**Schematic showing three phases of spilling breaking for weak and strong surface tension effects. (After Duncan, 2001.)**

# Wave Influences in Upper Ocean




1. The wave-stirred layer: the TKE production by wave breaking significantly exceeds the mean shear effect, and the turbulent diffusion of the wave kinetic energy dominates in the range of depths where the wave motion continues to be vigorous.
2. The turbulent diffusion layer: here the turbulent diffusion of TKE from the wave-stirred layer exceeds the wave (as well as the mean shear) effect in the TKE budget.
3. The wall layer: the mean shear production of turbulent energy dominates. In terms of the classic horizontally homogeneous and steady turbulent boundary-layer problem, this layer obeys wall-layer laws.