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In 2004/2005, the course NS-MO401m was given by prof.dr. J.T.F. Zimmerman.

Dynamische oceanografie (NS-MO401m)
5 July 2005

Question 1: Monsoon-currents

Figures 1a/1b on page 2 shows the average windfield over the Indian Ocean for January and July. Figures 2a/2b on page 3 shows for the same months the average wind-driven ocean circulation.

a) Make for both situations a drawing of the meridional distribution over the mid-N/S-axis of the ocean basin of:

- the zonal component of the windstress
- the meridional component of the vertically integrated meridionial Ekman-transport and its divergence
- the implied meridional shape of the sea-level

b) explain the zonal component of the wind-driven circulation as given in fig. 2a/b

c) give a qualitative explanation of the western intensification of the southen circulation cell (the Agulhas Current)

Question 2: Two-layer ocean

Consider the dimensionless stationary linearized quasigeostrophic potential vorticity equation, including forcing and friction, for a barotropic fluid in a β-plane ocean basin with a flat bottom:

$$\psi_{0x} + \nu\Delta\psi_0 = g(x, y) = -3\sin(3y) \tag{1}$$

a) which friction mechanism is used in this equation?

b) what is the physical explanation of the dimensional Ekman number ν?

c) using eq.(1) as a starting point, give the analogous equations for a *two-layer* density-stratified ocean with layers of the equal depth with a single Ekman number, ν, for all frictional boundary layers.

d) show that in this two-layer system the Sverdrup-balance in the interior leads to an equivalent barotropic situation

e) how can one use the assumption of an equivalent barotropic situation in order to make an estimate of the sealevel structure from an observation of the density structure of the ocean?

Question 3: Equatorial Kelvin wave

Consider the linearized frictionless barotropic shallow water equations for the β-plane ocean centered *at the equator*, with the constant depth, H:

$$U_t - f(y)v = -g\zeta_x \tag{2}$$

$$v_t + f(y)u = -g\zeta_y \tag{3}$$

$$u_x + v_y + w_z = 0 \tag{4}$$

a) what is the basic assumption behind the shallow water equations?

b) what is the expression for $f(y)$ for an equatorial β-plane?

c) (2)-(4) appear to give 3 equations for the 4 depedent variables (u, v, w, ζ); how can you remove this apparent degeneracy to 3 dependent variables (u, v, ζ)?

Using the result of c), show that here exists a so called Equatorial Kelvin wave with the following charactersitics by assumption:

- $v(x, y, t) = 0$
- $\zeta(x, y, t) = Z(y) \exp[\mathrm{i}(kx - \sigma t)]$

d) determine the form of Z(y) and show that it describes a wave trapped at the equator with trapping lengthscale $\lambda = \beta/c_0$, $c_0 = \sqrt{gH}$.

e) determine the disperion relation for this wave and show that, for a wave that has an amplitude that remains finite on an unbounded β-plane, the wave can only propagate from the west to east, with a phase propagation speed c_0

f) what is the energy propagation speed and direction?

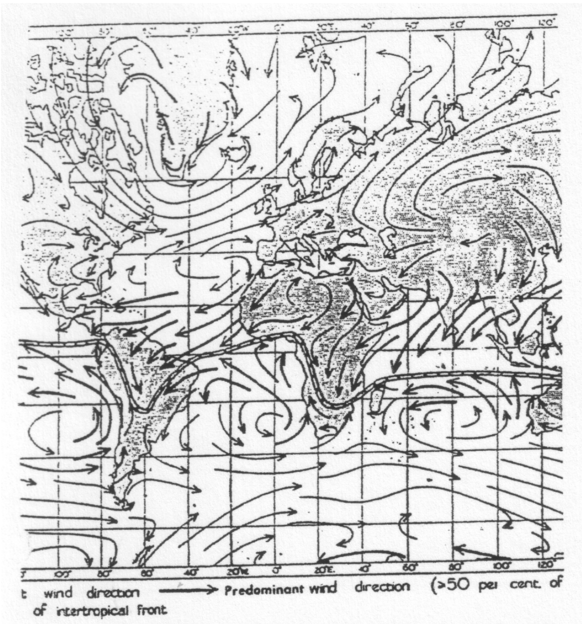

Fig. 4.22 Prevailing surface winds in January (approx. 1900–50).

Figure 1a: January

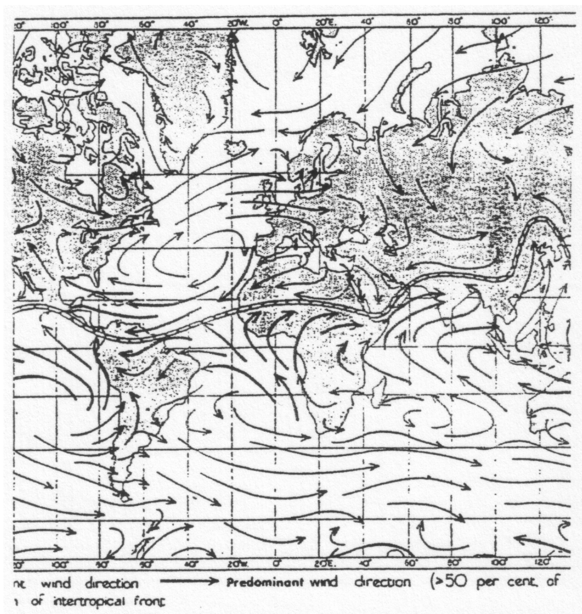

Fig. 4.23 Prevailing surface winds in July (approx. 1900–50).

Figure 1b: July

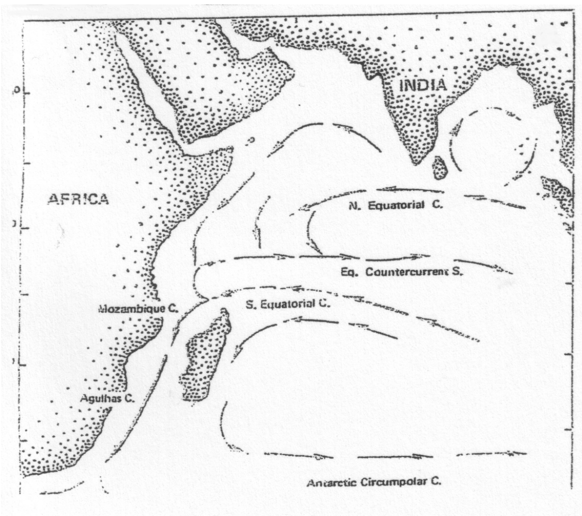

Figure 2a: January

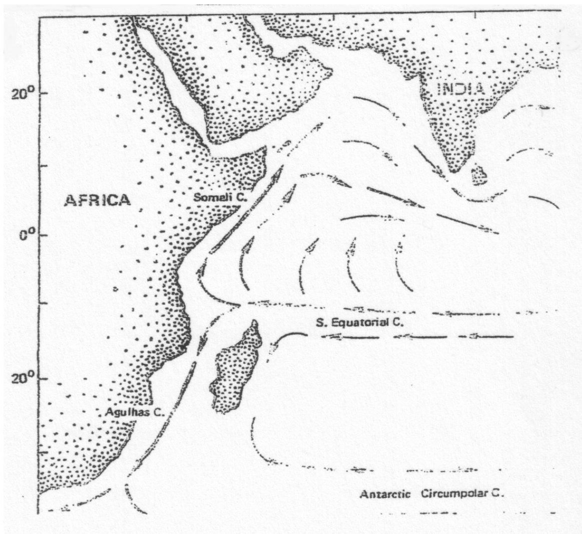

Figure 2b: July