Ekman Transport

- Ekman transport is the *direct* wind driven transport of seawater
- Boundary layer process
- Steady balance among the wind stress, vertical eddy viscosity & Coriolis forces
- Story starts with Fridtjof Nansen [1898]

Wind stress Calculation

- Direct measurement of wind stress is difficult.
- Wind stress is mostly derived from meteorological observations near the sea surface using the bulk formula with empirical parameters.
- The bulk formula for wind stress has the form

$$\vec{\tau} = C_d \rho_a V \vec{V}$$

Where ρ_a is air density (about 1.2 kg/m^3 at mid-latitudes), V (m/s), the wind speed at 10 meters above the sea surface, C_d, the empirical determined drag coefficient : Cd=0.0013

Fridtjof Nansen

- One of the first scientist-explorers
- A true pioneer in oceanography
- Later, dedicated life to refugee issues
- Won Nobel Peace Prize in 1922

Nansen’s Fram

- Nansen built the Fram to reach North Pole
- Unique design to be locked in the ice
- Idea was to lock ship in the ice & wait
- Once close, dog team set out to NP

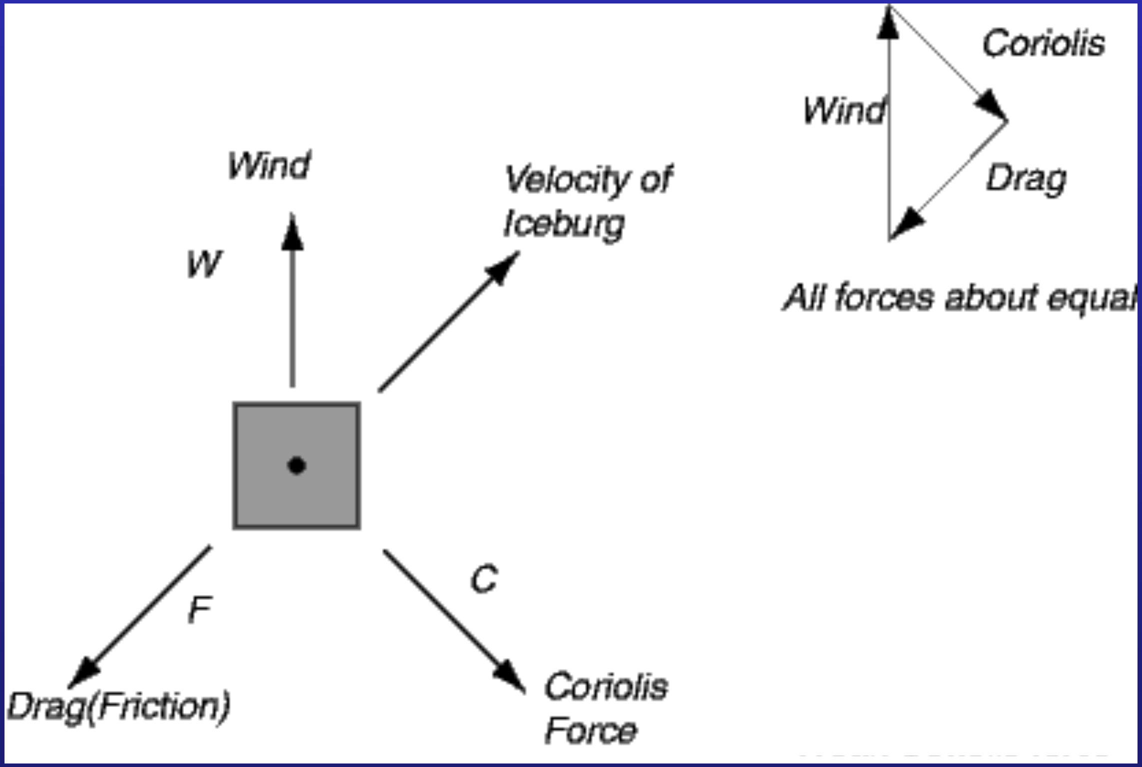
Fram Ship Locked in Ice

1893 -1896 - Nansen got to 86^{o} 14′ N

Ekman Transport

- Nansen noticed that movement of the ice-locked ship was 20-40^{o} to *right* of the wind
- Nansen figured this was due to a steady balance of friction, wind stress & Coriolis forces
- Ekman did the math

Ekman Transport



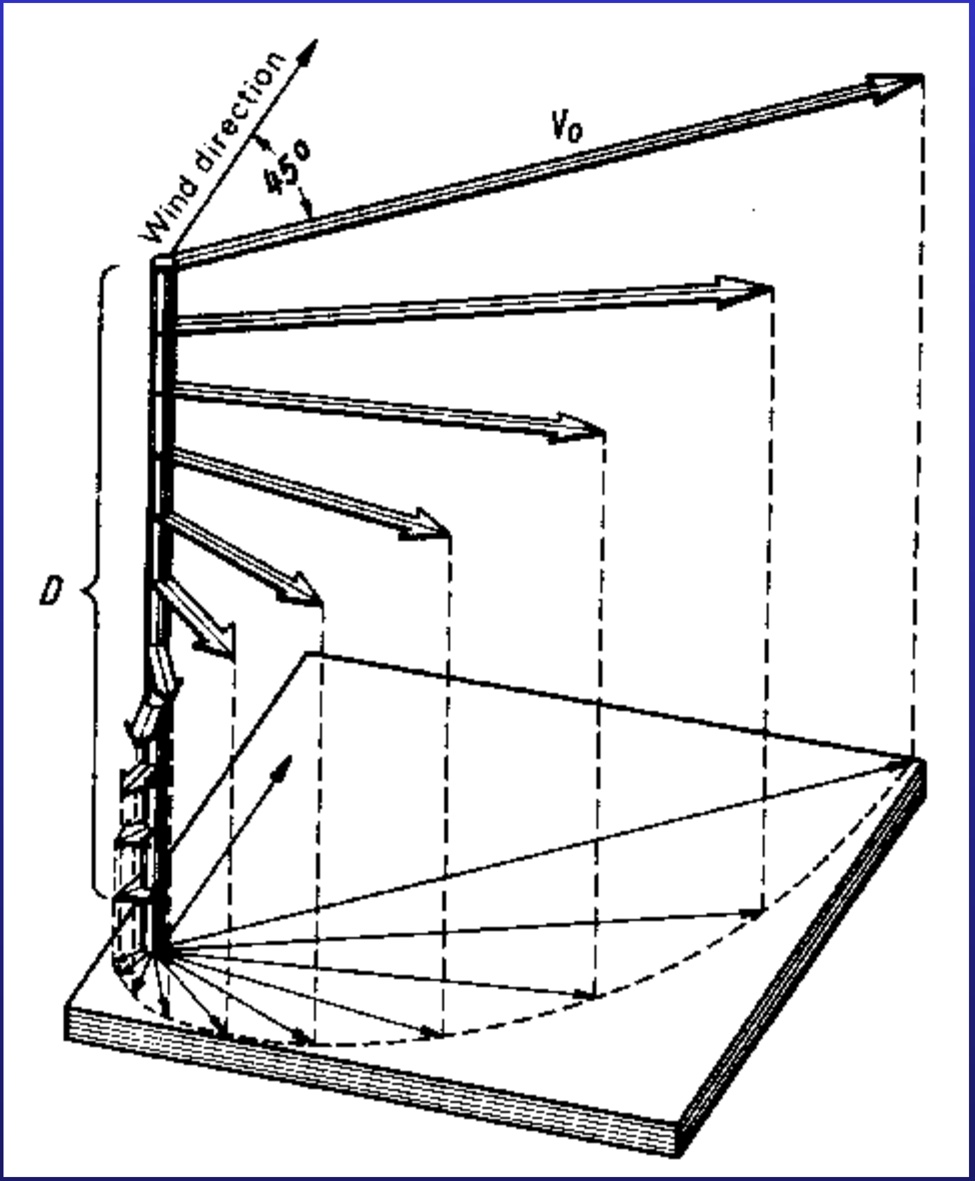
Motion is to the right of the wind

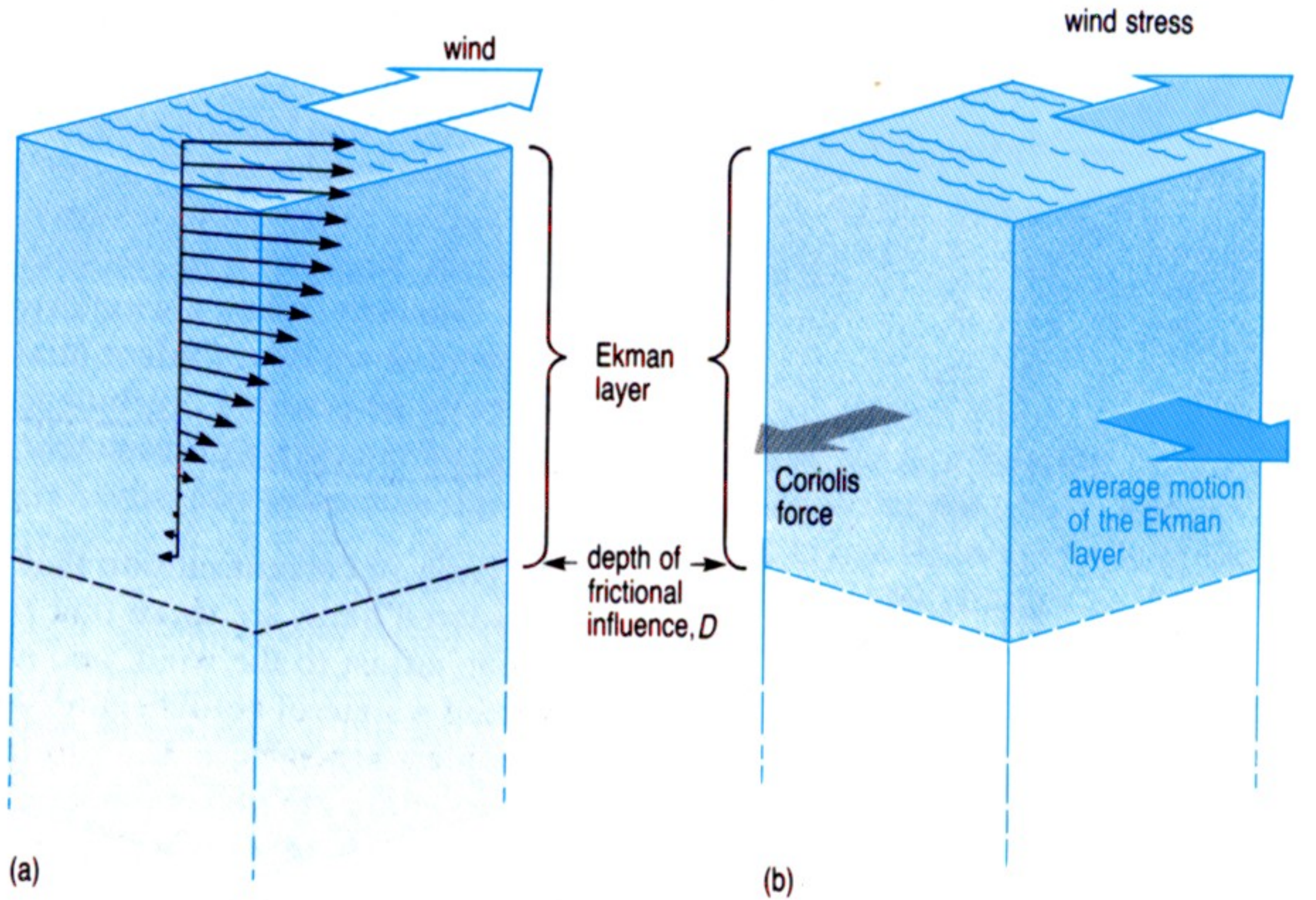
Ekman Transport

- The ocean is more like a layer cake
- A layer is accelerated by the one above it & slowed by the one beneath it
- Top layer is driven by τ_w
- Transport of momentum into interior is inefficient

Ekman Spiral

- Top layer balance of τ_w, friction & Coriolis
- Layer 2 dragged forward by layer 1 & behind by layer 3
- Etc.




wind
wind stress
Ekman
layer
Coriolis
force
average motion
of the Ekman
layer
depth of
frictional
influence, D
(a)
(b)

Ekman Transport

- Balance between wind stress & Coriolis force for an Ekman layer
  - Coriolis force per unit mass = $f\ u$
    - u = velocity
    - f = Coriolis parameter = $2\ \Omega \sin \phi$

      $\Omega = 7.29\times10^{-5}\ s^{-1}$ & ϕ = latitude
- Coriolis force acts to right of motion

Ekman Transport

Coriolis = wind stress

$$f\, u_e = \tau_w / (\rho D)$$

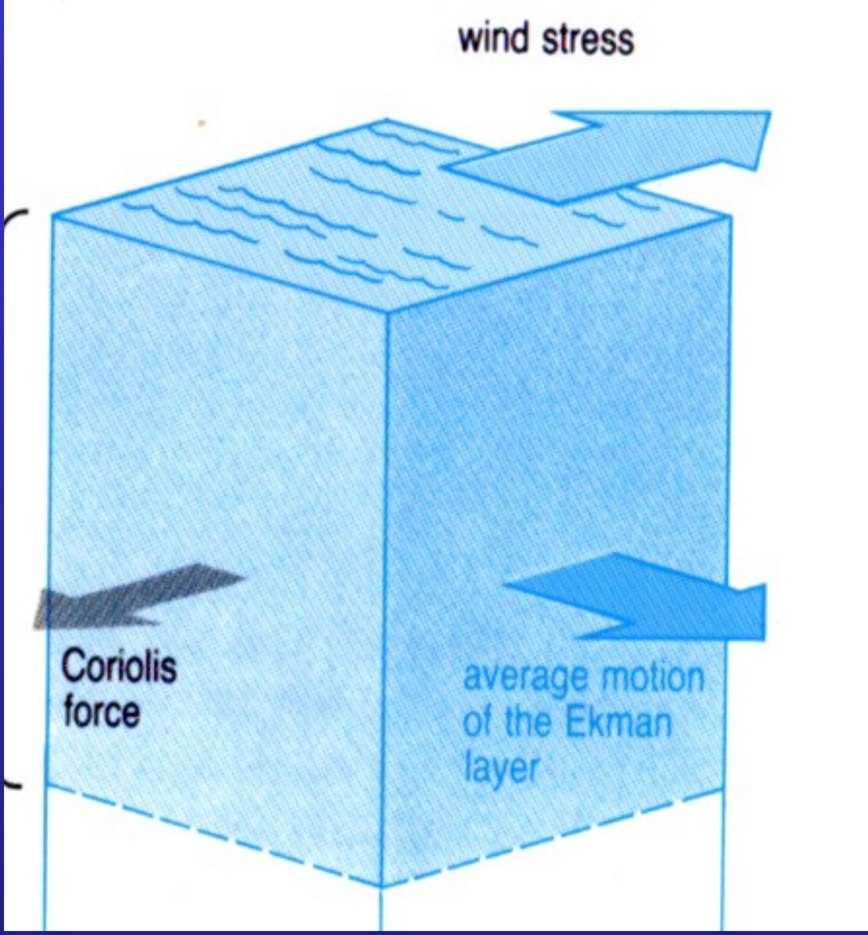
Ekman velocity = u_e

$$u_e = \tau_w / (\rho f D)$$

Ekman transport = Q_e

$$Q_e = \tau_w / (\rho f) = [m^2 s] = [m^3 s^{-1} m^{-1}]$$

(Volume transport per length of fetch)



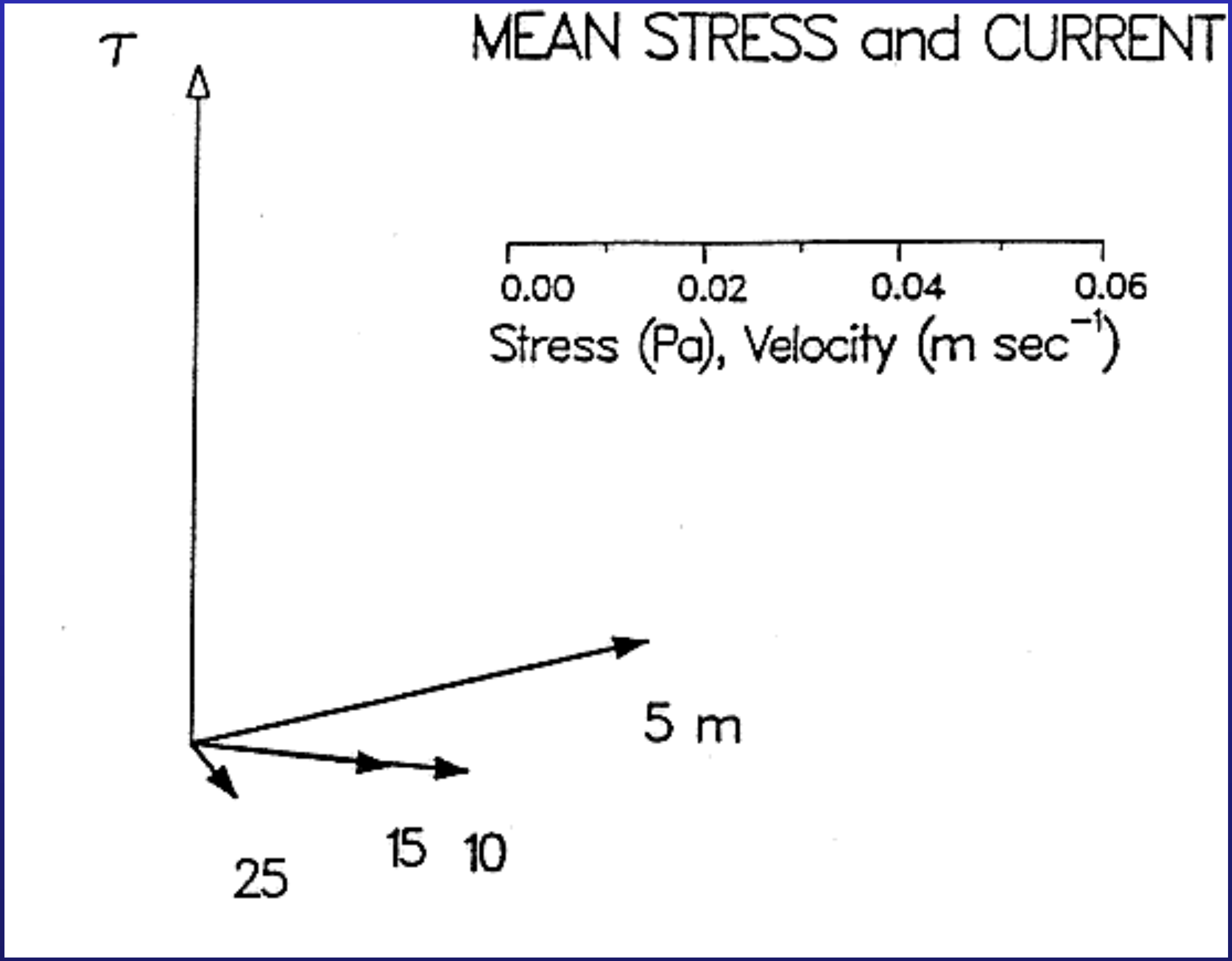
Ekman Transport

- Ekman transport describes the *direct* wind-driven circulation
- Only need to know τ_w & f (latitude)
- Ekman current will be right (left) of wind in the northern (southern) hemisphere
- Simple & robust diagnostic calculation

Ekman Transport Works!!

- Averaged the velocity profile in the downwind coordinates
- Subtracted off the “deep” currents (50 m)
- Compared with a model that takes into account changes in upper layer stratification
- Price et al. [1987] *Science*

Ekman Transport Works!!



Ekman Transport Works!!