ATOC 5051 INTRODUCTION TO PHYSICAL OCEANOGRAPHY

Lecture 16

Objectives:

1 Equatorial waves (continue previous class)
2 Summary of ocean waves & practice
3 Go over Midterm exam *(slides will be posted)*

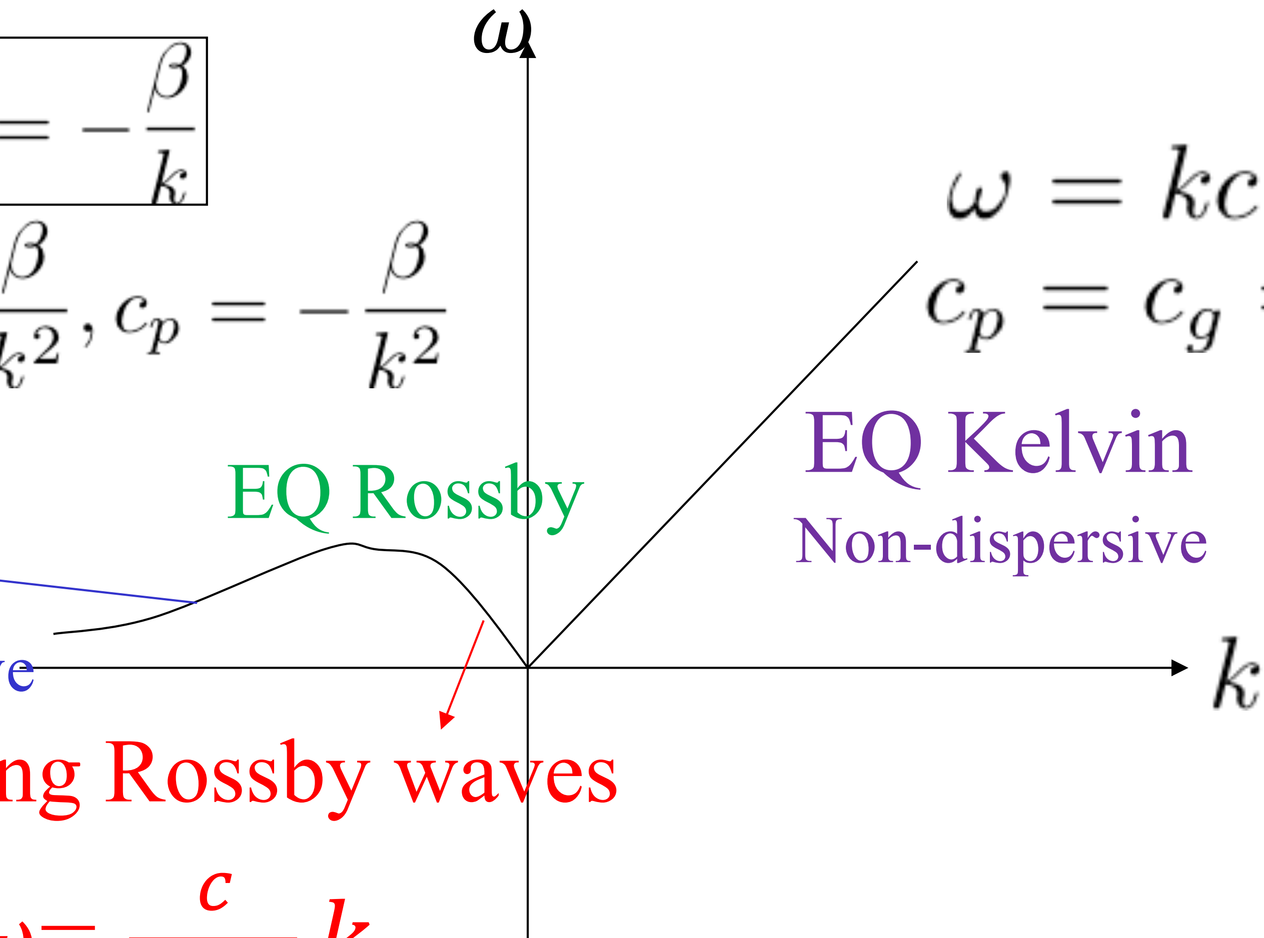
Previous class:

Dispersion relations: equatorial Kelvin & Rossby waves

$$\boxed{\omega = -\frac{\beta}{k}}$$

$$c_g = \frac{\beta}{k^2}, c_p = -\frac{\beta}{k^2}$$

$$\omega = kc,$$
$$c_p = c_g = c$$



$$\omega = -\frac{c}{2l+1}k$$

$$c_g = c_p = -\frac{c}{2l+1}$$ Non-dispersive

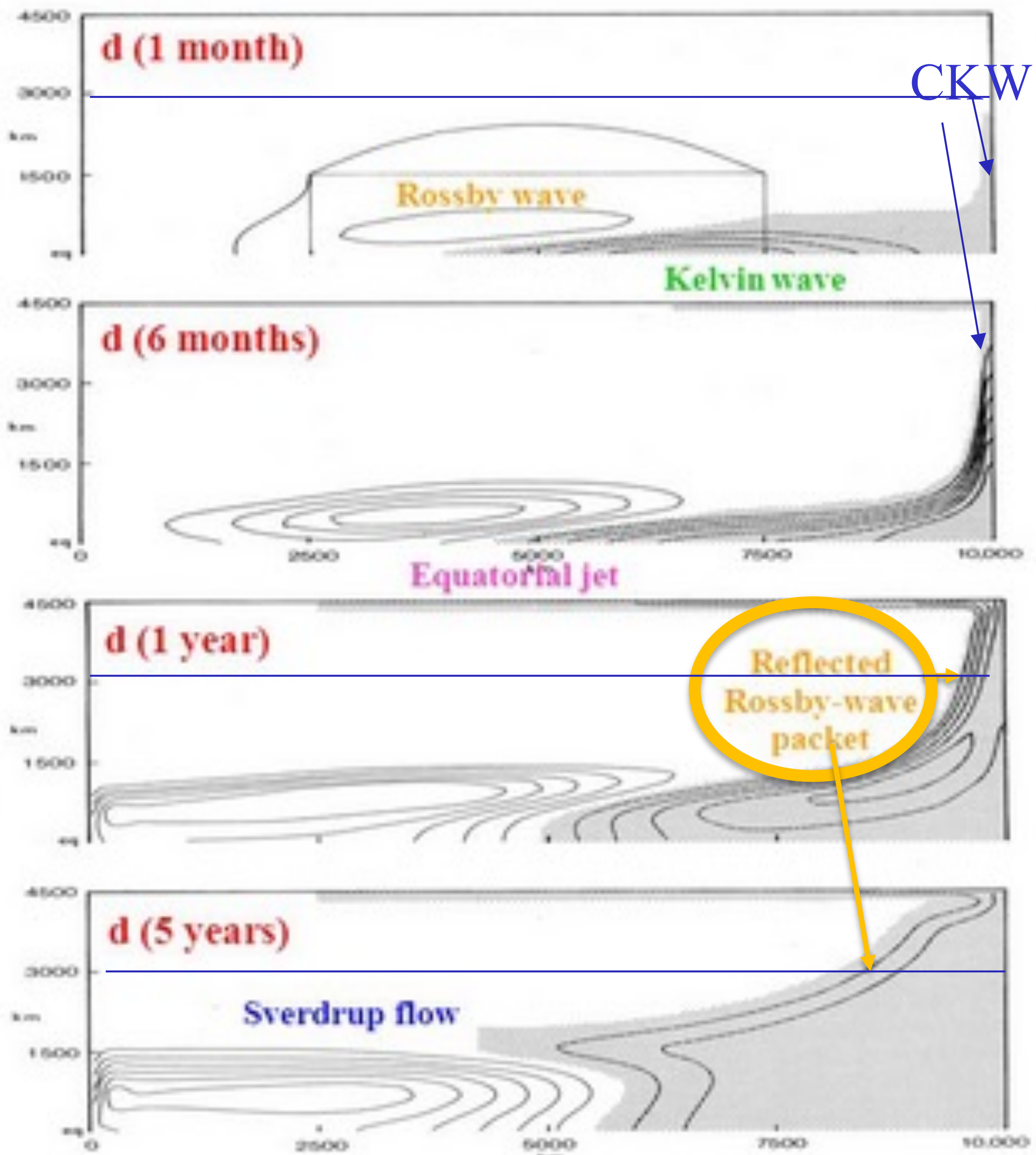
Eastern-boundary reflections

Easterly wind

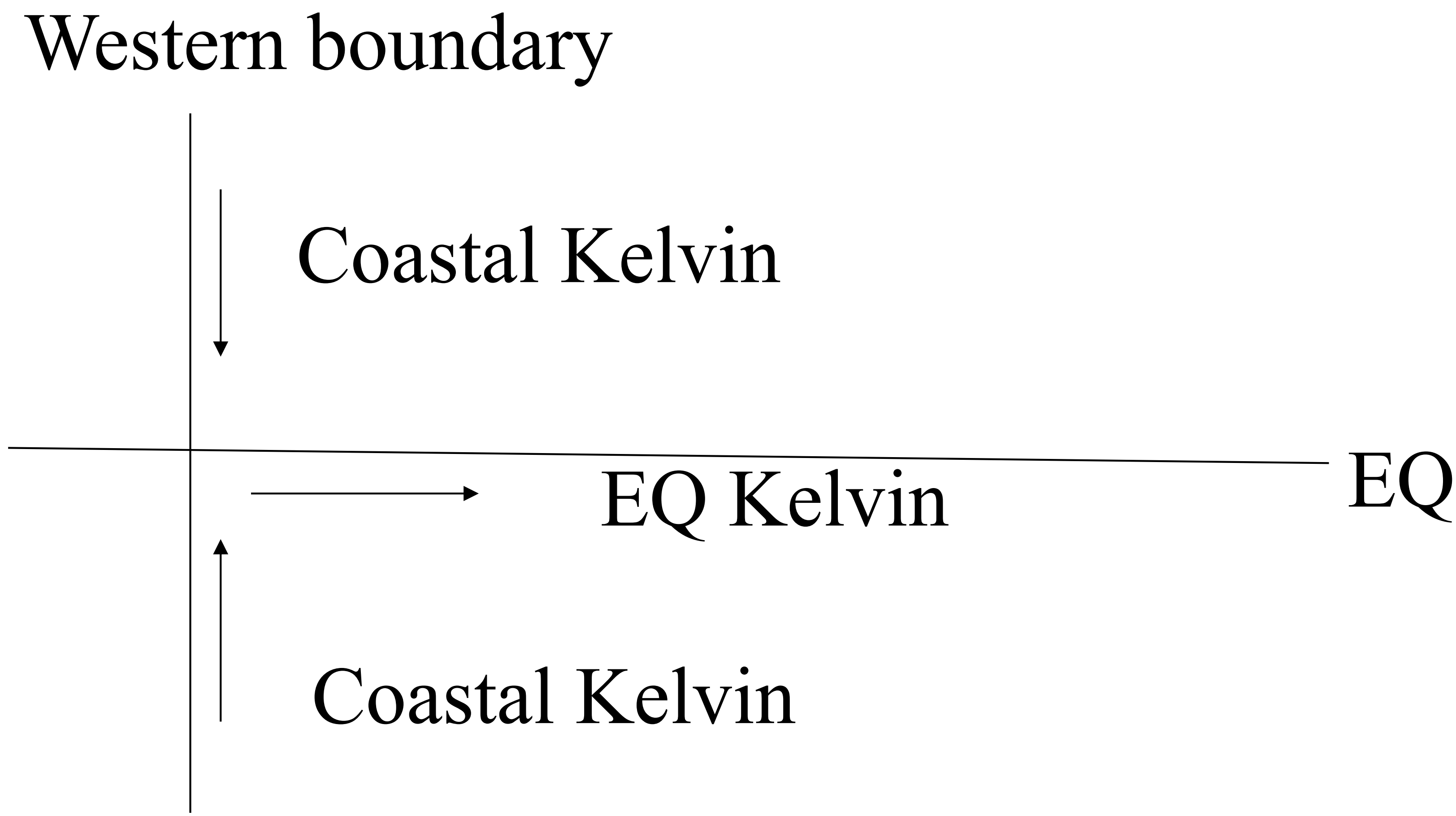
Forcing: Board demo

In response to forcing by a **patch of wind in the interior ocean**, **Kelvin waves reflect from the eastern boundary**, creating a **characteristic wedge-shaped pattern**. In addition, wind-generated **Rossby waves reflect from the western boundary** to return to the interior ocean.

After multiple reflections, the solution eventually **adjusts to a state of Sverdrup balance**.



Off equatorial influence:



(iii). Equatorially-trapped inertial gravity waves (IGW)

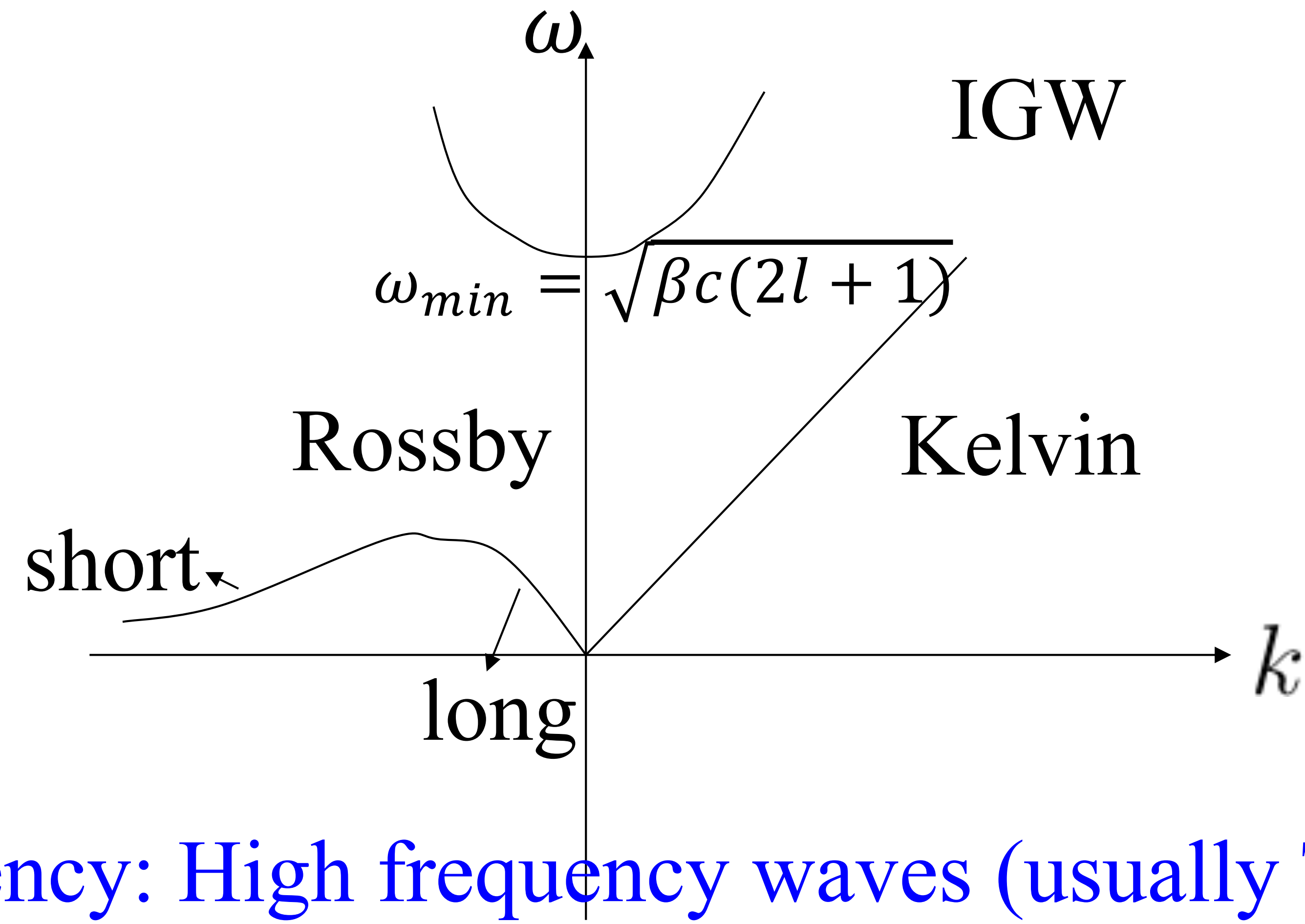
a) Dispersion relation:

$$\omega^2 = k^2c^2 + \beta c(2l + 1),$$

l =1, 2, … is the order number for Hermite function.

They are similar to the IGWs in mid-latitude, which are gravity waves under the influence of β at the equator and of f in mid-latitude.

The equatorially-trapped IGWs are dispersive; energy and phase can propagate both eastward and westward.



Frequency: High frequency waves (usually T: hours, days…)

b) Solution.

IGWs have the same solution form as the equatorial Rossby waves: they are oscillating in y direction and meanwhile decay poleward. Their e-folding decay scale is equatorial Rossby radius: $a_e = \sqrt{\frac{c}{2\beta}}.$

c) Symmetric property.

Can be both symmetric or anti-symmetric about the equator. [Note: if u & p are symmetric, we call them symmetric waves.]

d) Forcing.

High-frequency gusty winds, tides, etc.

(iv). Yanai waves or mixed Rossby-gravity waves (MRGW)

a) Dispersion relation

$$k = -\frac{\beta}{\omega} + \frac{\omega}{c}.$$

b) Solution

(it is the $l = 0$ case)

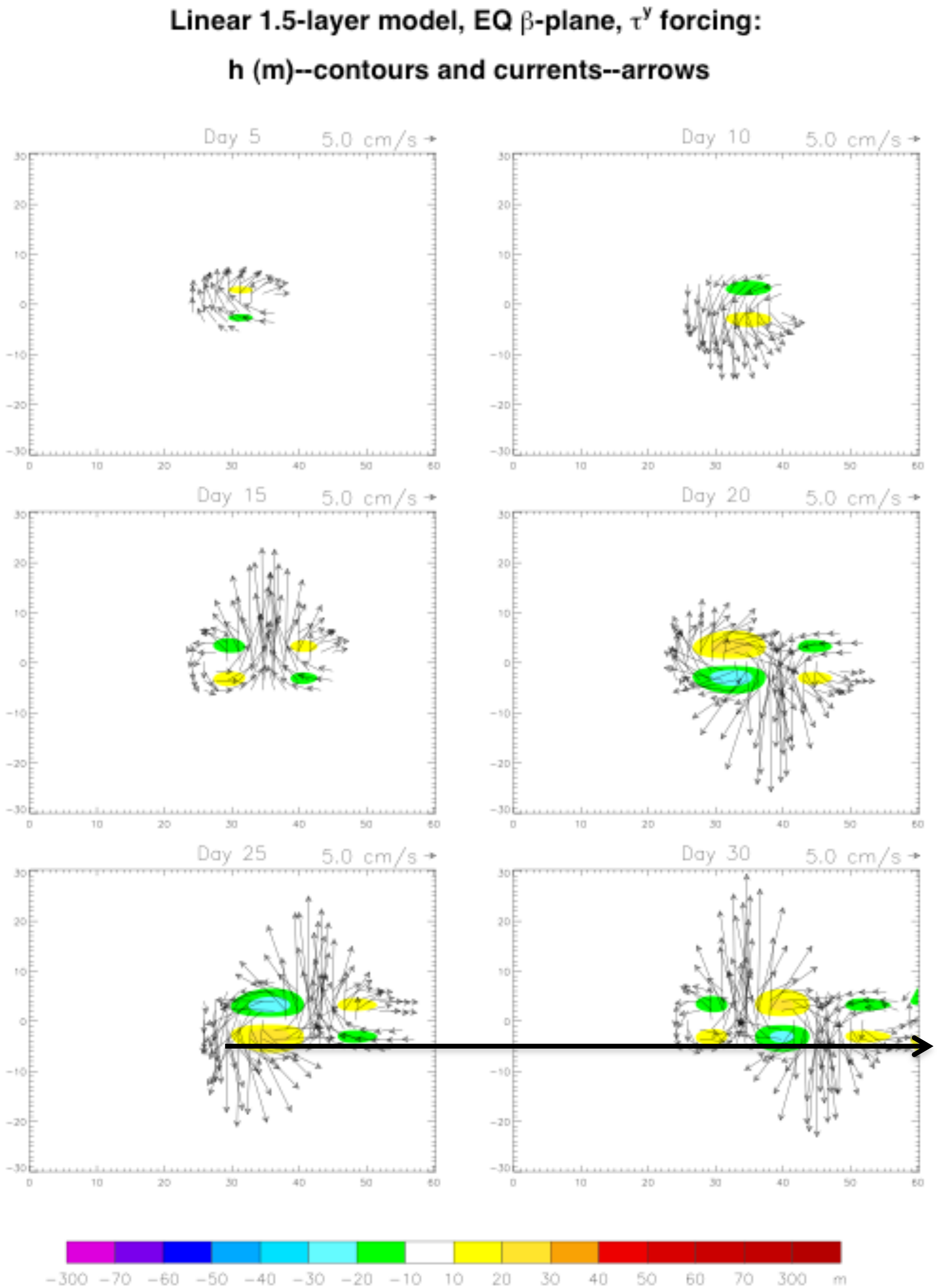
c) Symmetric property:

Anti-symmetric

d) Forcing:

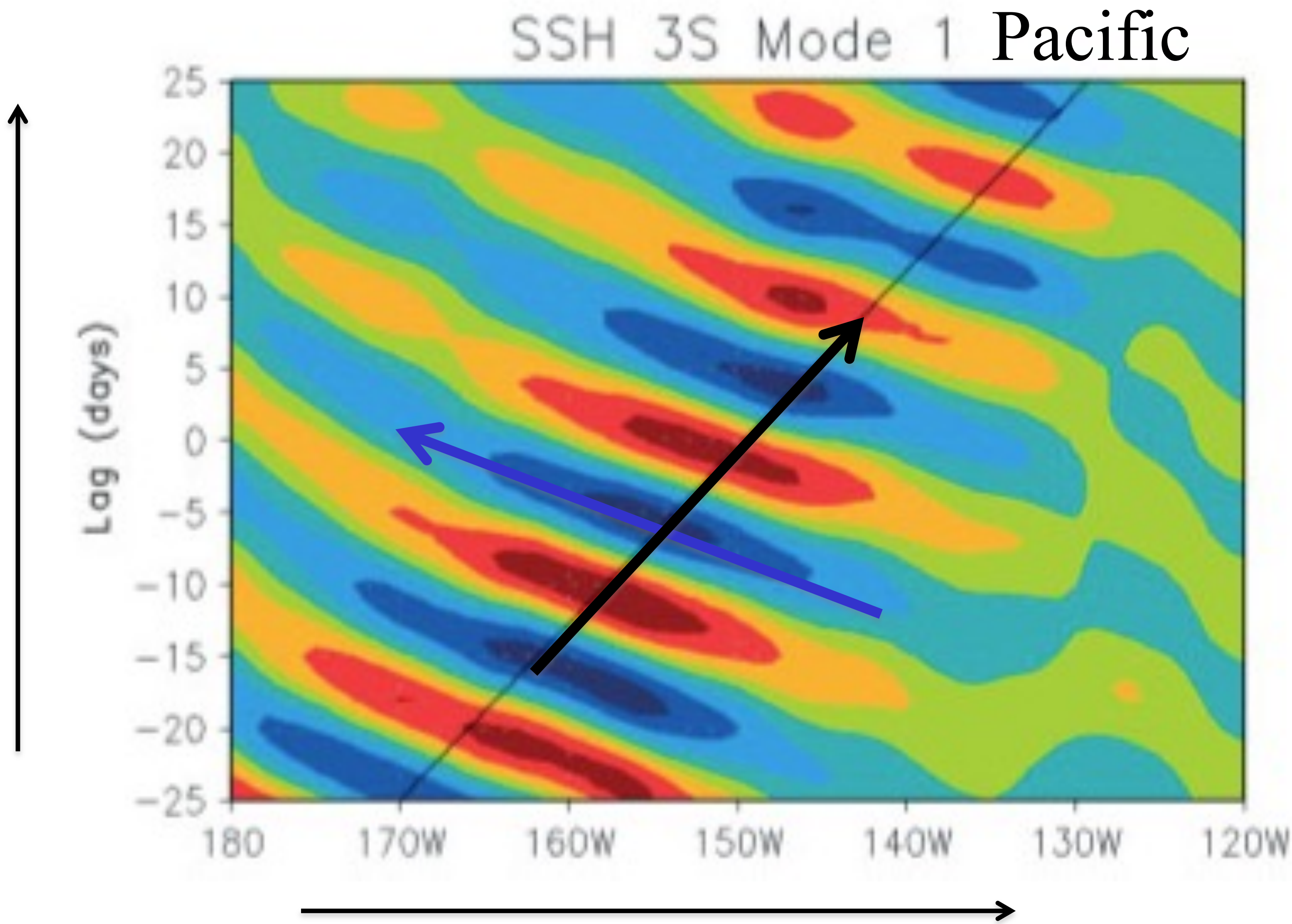
Anti-symmetric winds (say, meridional winds)

Yanai waves:


Linear 1.5-layer model, EQ β-plane, τ^y forcing:
h (m)--contours and currents--arrows
Day 5
Day 10
Day 15
Day 20
Day 25
Day 30
5.0 cm/s
-300 -70 -60 -50 -40 -30 -20 -10 10 20 30 40 50 60 70 300 m

Which direction is C_p?
Which direction is C_g?

Shinoda, 2012
Q. J. R. Meteorol. Soc.138: 1018 – 1024

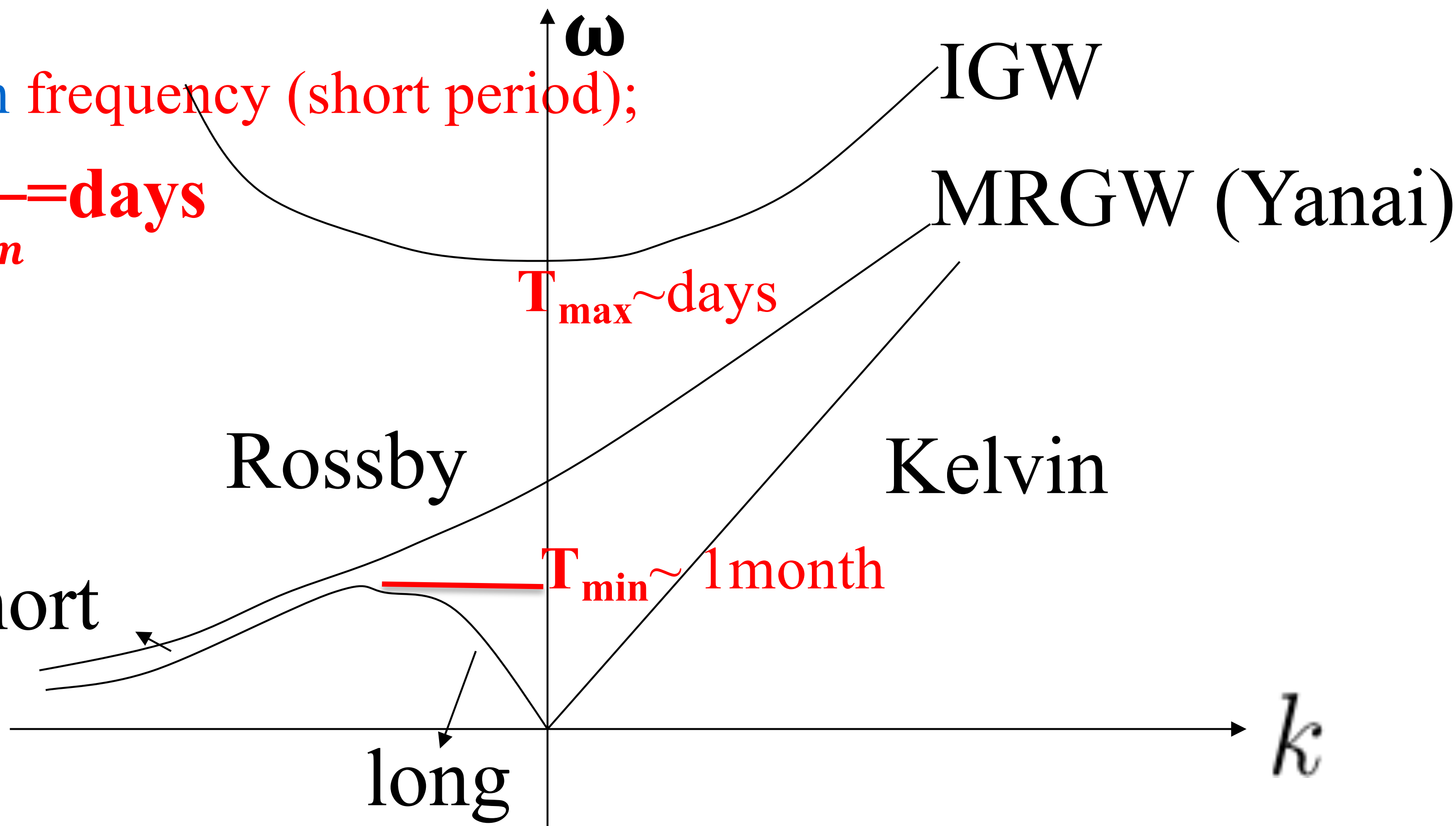


Blue: negative; red: positive

Summary for wave section & practice

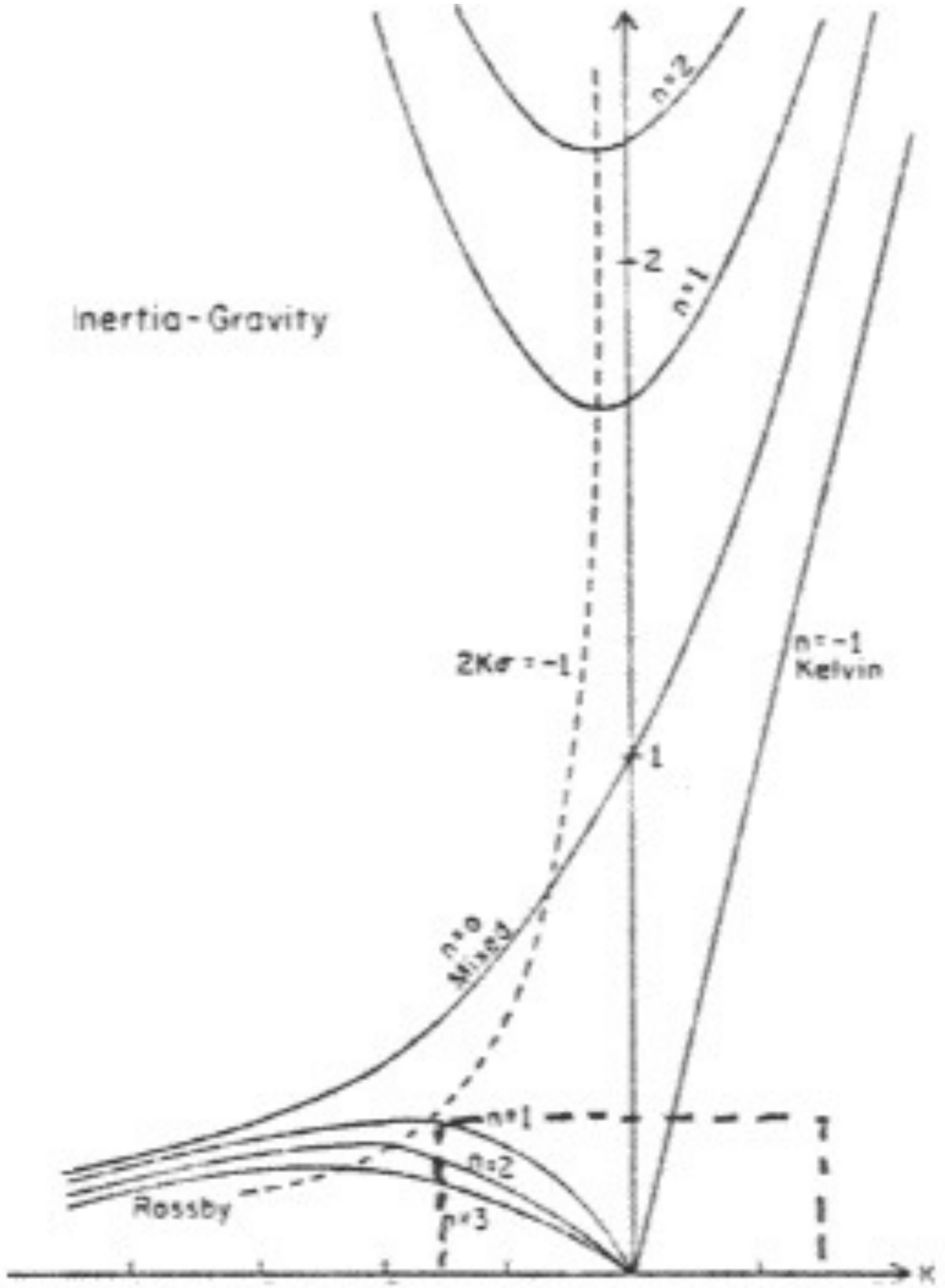
IGWs: high frequency (short period);

$$\mathbf{T_{max}=\frac{2\pi}{\omega_{min}}=days}$$



Rossby waves: low frequency (long period);

T_{min}=1 month



Dispersion relationship for modes of the linear shallow water equations, from Cane and Sarachik (1976).

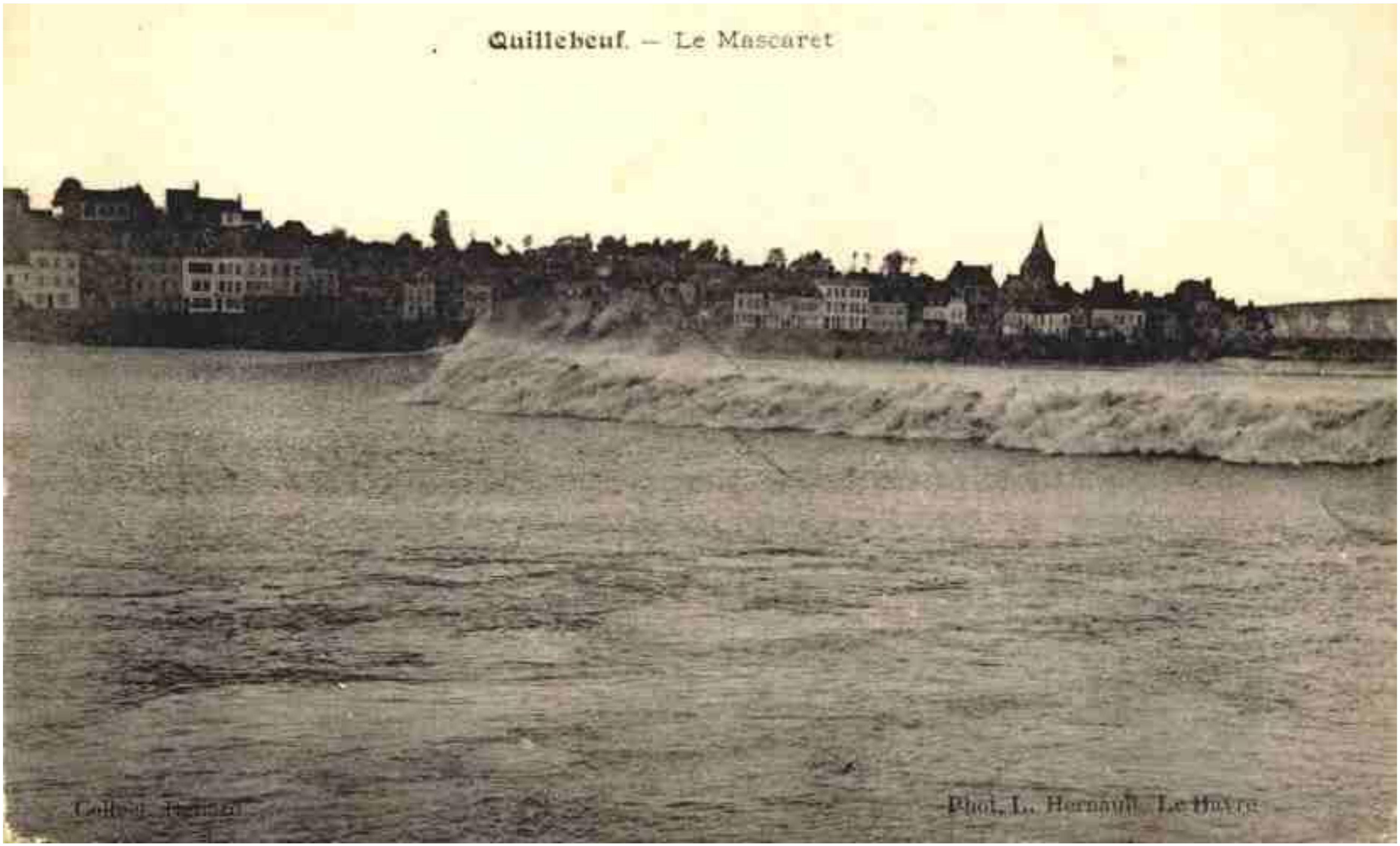
The dashed box near the origin is the region of frequency-wavenumber space relevant to ENSO.

Here, n is the meridional mode number, which is our l discussed above and is more common in physical oceanography research

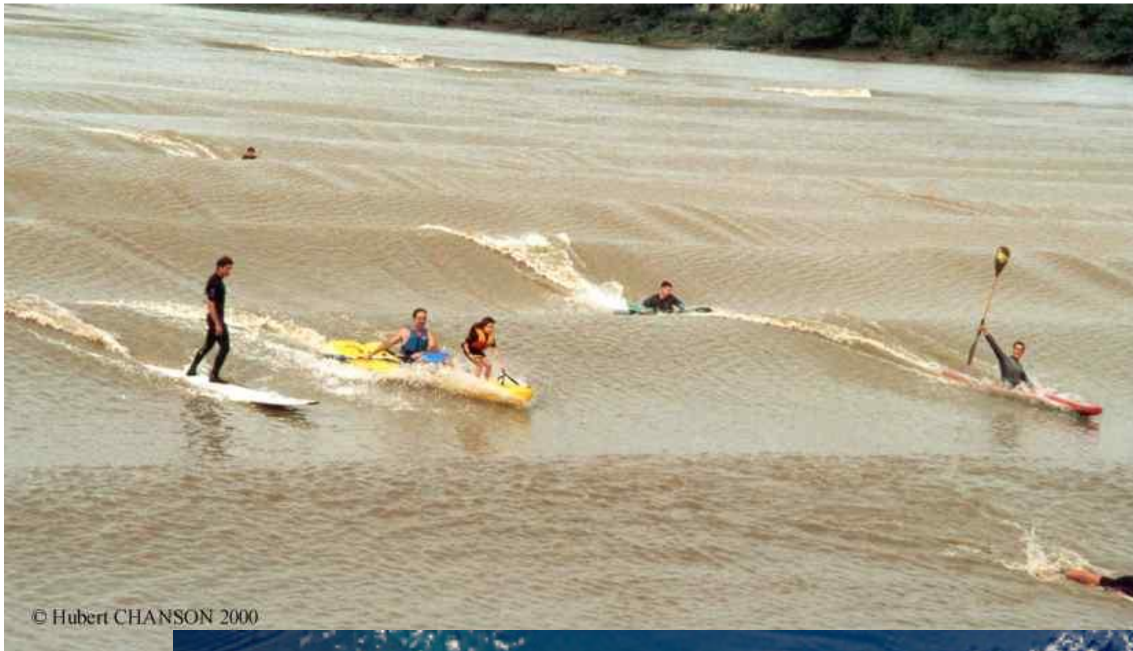
Forcing: winds at corresponding frequency (period)

So far, we have learnt:
Gravity waves (surface & internal)

Below: long surface gravity waves: Oceanic bore

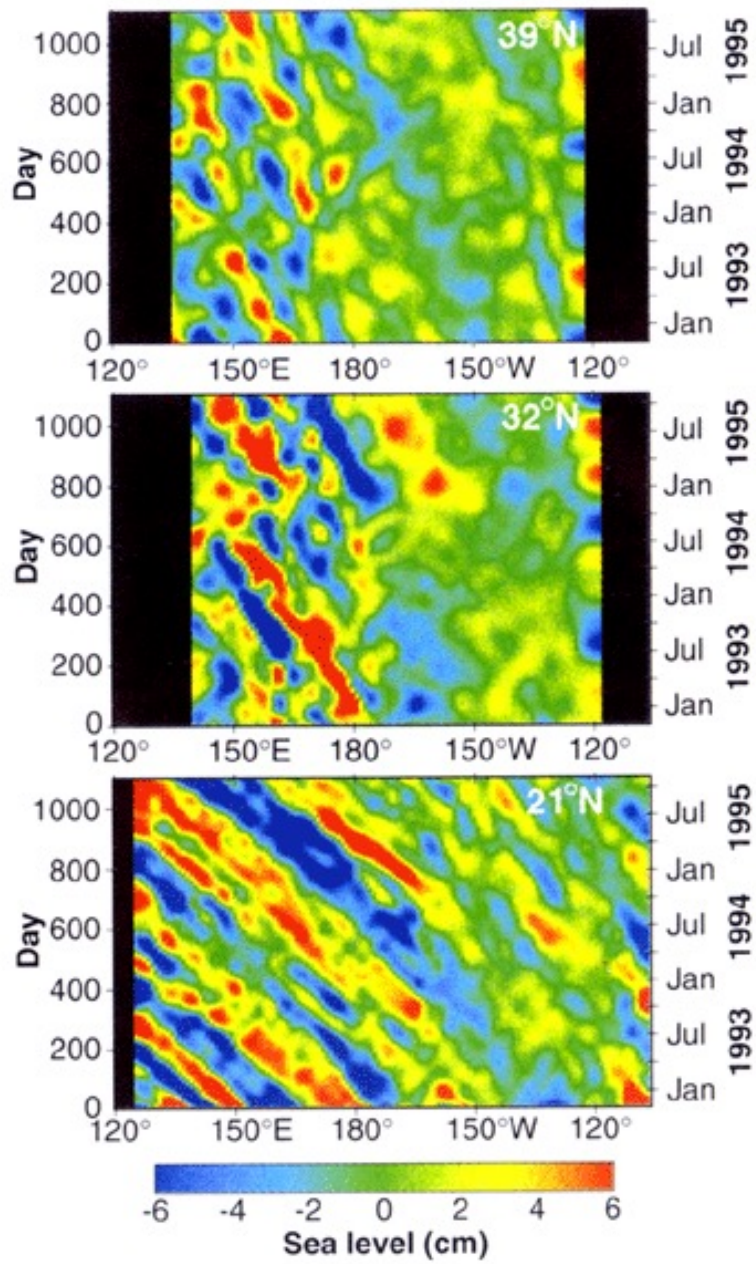


Surface gravity waves: long & short



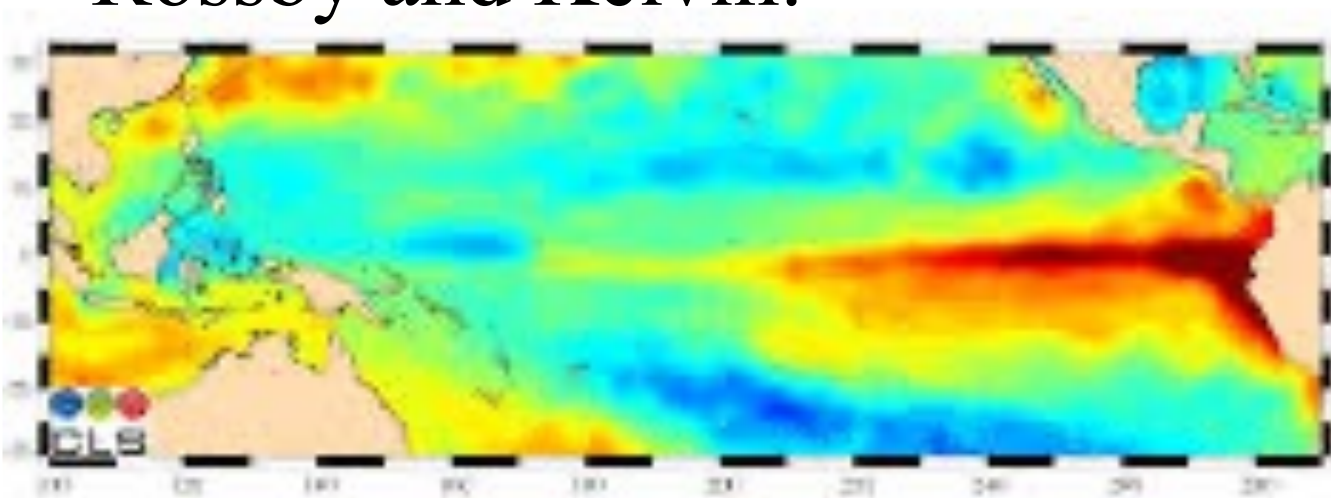
Internal wave
(photo from space)

Mid-latitude Rossby waves



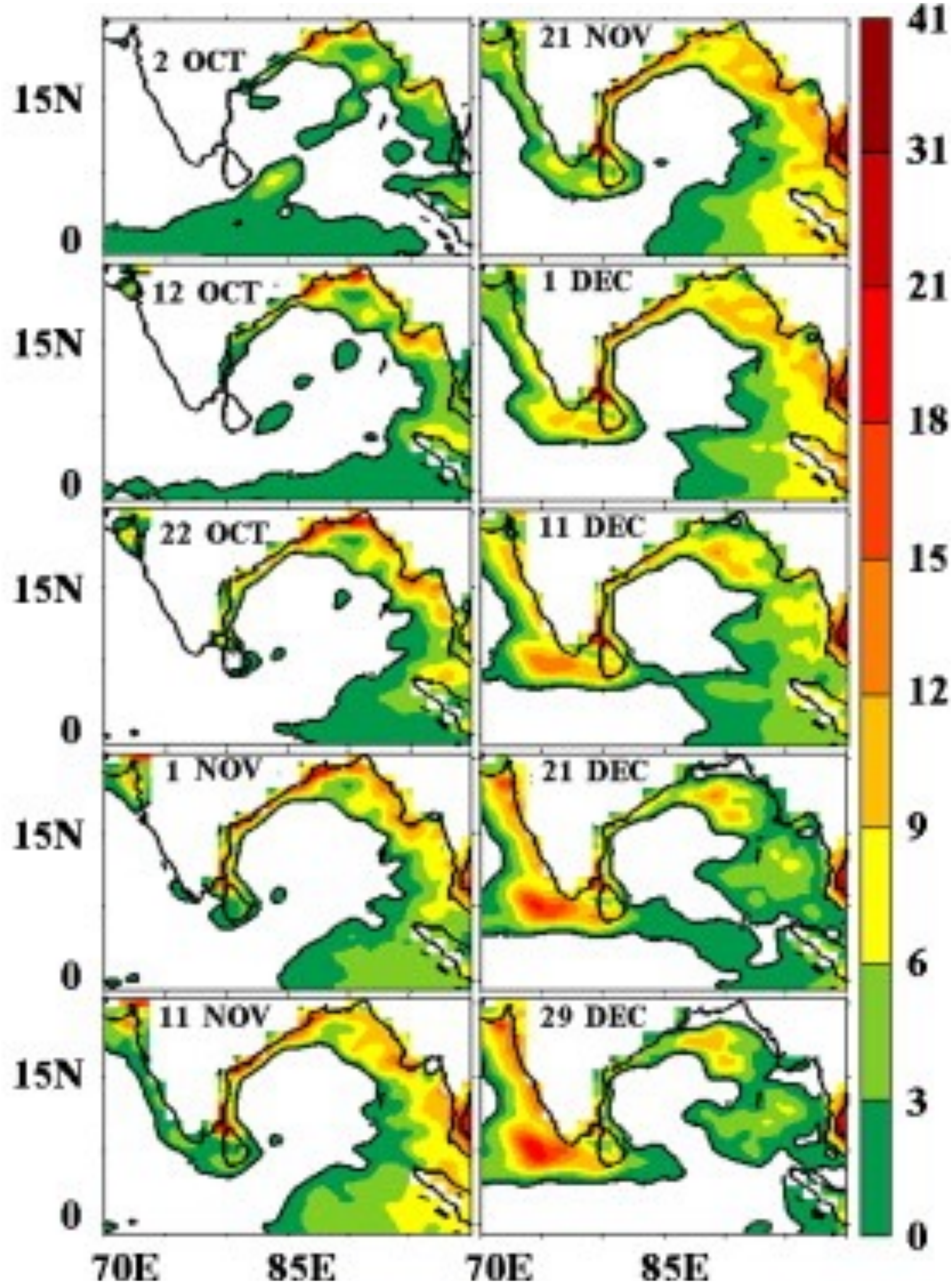
Equatorial waves:

Rossby and Kelvin:

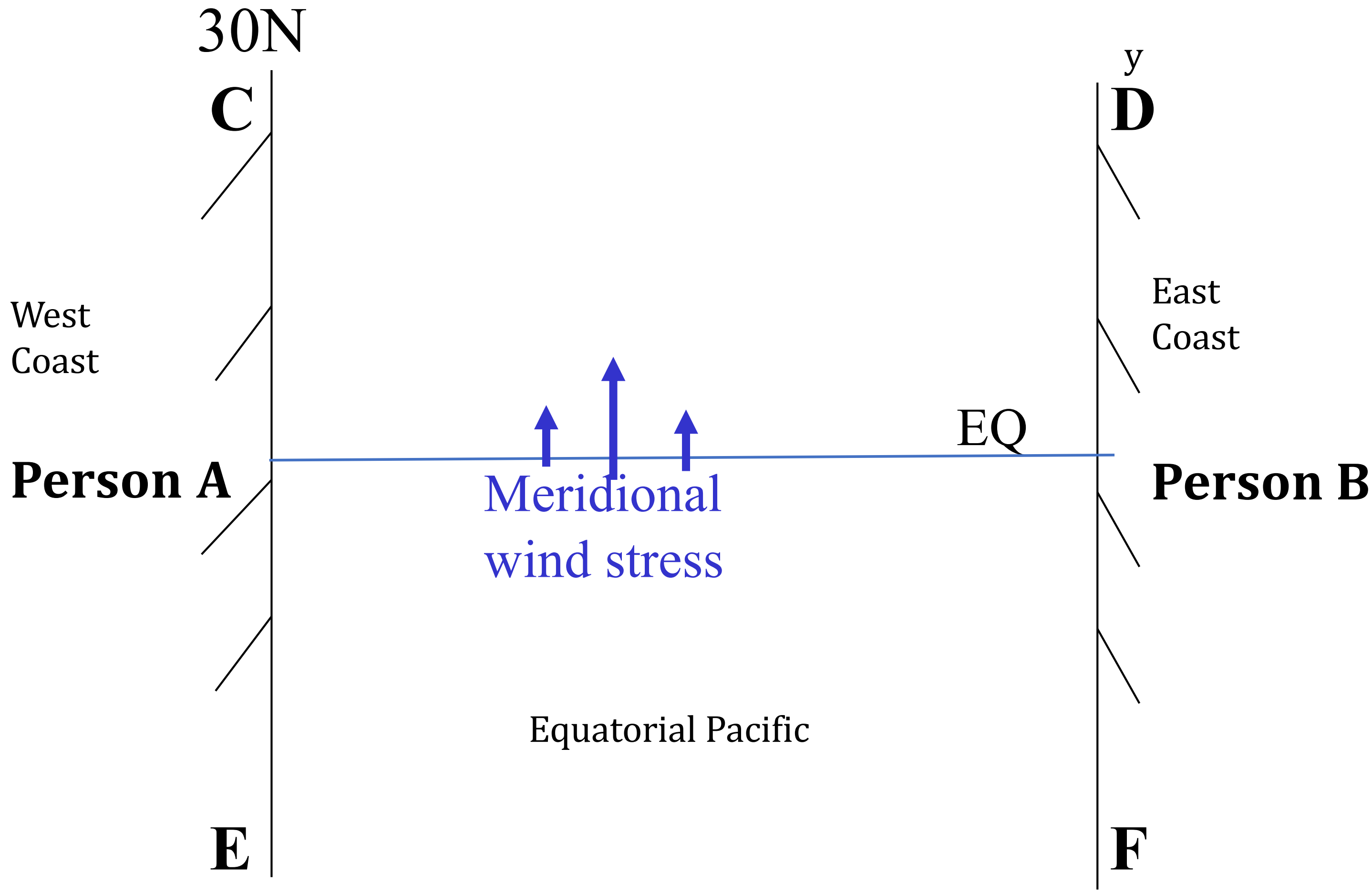


https://www.youtube.com/watch?v=VNefCmc3_1Y

Coastal Kelvin wave



Breakout session 1



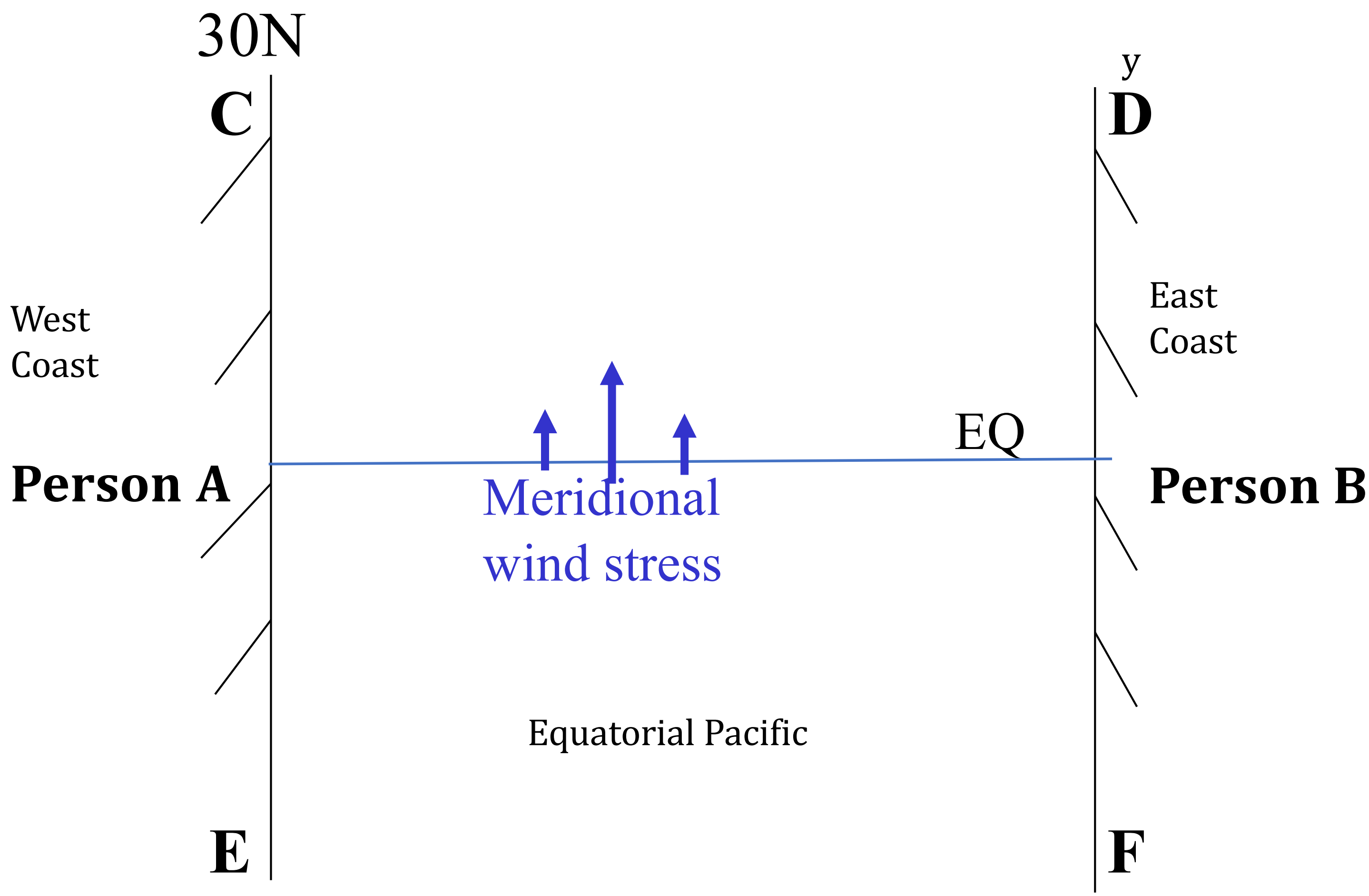
Question:

Meridional wind forcing with T=15days;

Will person A, B, C, D, E, F observe sea level variability signals?

If yes, through what process? If no, why?

Breakout session 2



Question:

Meridional wind forcing with T=400days;
Will person A, B, C, D, E, F observe sea level variability signals?
If yes, through what process? If no, why?