Question X: Which quantity is NOT a material invariant of the SWE system? (1p)

a) potential vorticity

b) density

c) volume

d) energy

Question X: How many material invariants has a SWE system described by the conservation of potential vorticity? (1p)

a) one

b) three

c) infinite number

d) none

Question X: A wind flow passes by a mountain, leading to squeezing of the fluid column. Assume a rigid lead over the flow. What is going to happen? (1p)

a) the angular momentum cannot be conserved in that case

b) negative relative vorticity will be generated

c) positive relative vorticity will be generated

d) no vorticity will be generated

Question X: The vertical velocity in a shallow water system: (1p)

a) is a prognostic variable, which evolution is governed by the momentum equation

b) is a prognostic variable, which evolution is governed by the conservation of PV

c) is a diagnostic variable diagnosed from the continuity equation

d) is a diagnostic variable calculated as a y-derivative of the streamfuntion

Question X: Choose the correct statement: (1p)

a) Short Rossby waves have high propagation speed

b) Long Rossby waves are non-dispersive and short Rossby waves are nearly stationary

c) Long Rossby waves are dispersive and short Rossby waves are nearly stationary

d) Long Rossby waves are dispersive and so are the short Rossby waves

Question X: Choose a correct statement: (1p)

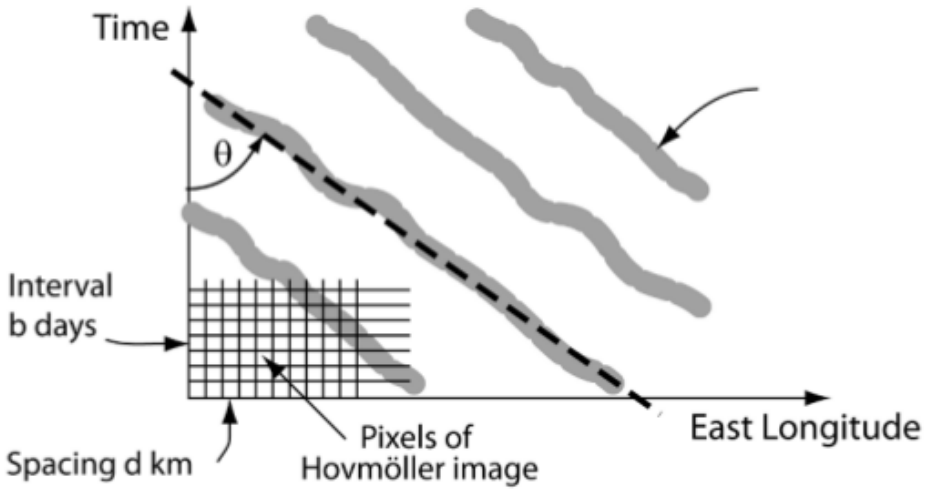
a) Poincare waves are always dispersive, even in asymptotic cases of short- and long-wave limits.

b) Poincare waves are always non-dispersive, even in asymptotic cases of short- and long-waves.

c) Poincare waves are in general dispersive but in the short-wave asymptotic limit they are non-dispersive

d) Poincare waves are in general non-dispersive but in the short-wave asymptotic limit they are dispersive

Question X: What kind of wave was measured on the figure below? (1p)



a) Barotropic Poincare waves

b) Coastal Kelvin waves

c) Equatorial Kelvin waves

d) Rossby waves

Question X: Which of the processes listed below are NOT well represented under the QG approximation: (1p)

a) Rossby waves in the presence of the Jet Stream

b) Ocean eddies on the beta plane characterized by small local ratio of relative vorticity and planetary vorticity ($\zeta/f \approx 0.1$)

c) Equatorial Rossby waves

d) Convective storms

Question X: Choose a correct statement: (1p)

a) Coastal Kelvin waves will propagate perpendicular to the coast on the Northern Hemisphere

b) Coastal Kelvin waves will propagate with the coast to the left on the Northern Hemisphere

c) Coastal Kelvin waves will propagate with the coast to the left on the Southern Hemisphere

d) Coastal Kelvin waves will propagate with the coast either to the left or to the right on the Southern Hemisphere depending on the local Rossby radius of deformation.

Question X: The Madden-Julian Oscillation (MJO) is primarily associated with: (1p)

a) Rossby waves in the mid-laitudes

b) Polar vortex

c) Equatorial Kelvin waves

d) Atmospheric tides

Question X: Which waves are non-dispersive and their phase and group velocities are equal: (1p)

a) Poincare waves in a channel

b) Coastal Kelvin waves and long Rossby waves

c) Coastal Kelvin waves and Rossby waves with horizontal scales slightly smaller than Rossby radius of deformation

d) None of these

Question X: Which of the processes listed below are NOT well represented under the QG approximation: (1p)

a) Long Rossby waves

b) Ocean eddies on the beta plane characterized by small local ratio of relative vorticity and planetary vorticity (slow rotation compared to planetary rotation)

c) Sverdrup circulation

d) Poincare waves

Question X: Which waves are triggered by West Wind Bursts and are used in forecasting as early warning for El-Nino events: (1p)

a) Poincare waves

b) Equatorial Kelvin waves

c) Equatorial Rossby waves

d) Coastal Kelvin waves

Question X: With which velocity does the energy associated with a barotropic Poincare wave propagate in ocean basin of depth H: (1p)

a) Group velocity which is always $c = \sqrt{gH}$

b) Group velocity which is calculated as $\mathbf{c_G} = (c_G^x, c_G^y)$

c) Phase velocity $c = \omega/k$

d) u and v, depending on the direction

Question X: Choose the correct statement: (1p)

a) Rossby waves will always propagate to the west

b) Rossby waves will propagate to the west or east, depending on wavenumber k

c) Equatorial Kelvin waves will propagate to east or west, depending on f

d) Poincare waves will propagate along the coast

Question X: The Rayleigh–Kuo stability criterion for the flow described by Eq. 3 states that: "if $\frac{dq_o}{dy}$ (background vorticity gradient) does not change sign anywhere in the interior of the domain, the flow is stable". Choose a correct statement: (1p)

a) This is a sufficient condition for instability

b) This is a sufficient condition for stability

c) This is a necessary condition for stability

d) Neither of a-c is correct

Question X: The Kelvin circulation theorem is primarily associated with: (1p)

a) Kelvin-Helmholtz instabilities

b) Kelvin waves

c) Conservation of potential vorticity

d) Barotropic instability

Question X: The flow described by the 1-layer SWE system given by eqs. (1–2) admits solutions for so-called "fast mode(s)" and "slow mode(s)". Choose a correct statement describing these "modes": (1p)

a) The "fast mode(s)" refer to the solutions that are retained under the QG approximation while the "slow modes" are not

b) The "fast modes" are the Poincare, Kelvin and Rossby waves with phase speed larger than $c = \sqrt{gH}$ while the "slow mode(s)" have lower phase speed than c

c) The "fast mode(s)" are all possible wave solutions of this system and the "slow mode" refer to the geostrophic flow solution

d) The "fast mode(s)" are the linear Poincare and Kelvin wave solutions and the "slow mode(s)" are the geostrophic flow and Rossby Wave solutions

Question X: Choose the correct statement: (1p)

a) Barotropic Rossby radius of deformation corresponds to a length scale over which the rotational effects become important in a flow with two density layers and depends on reduced gravity

b) Barotropic Rossby radius of deformation corresponds to a length scale over which the beta effect (change of the Coriolis parameter with latitude) become important in a one-layer SWE

c) Barotropic Rossby radius of deformation corresponds to a length scale of a geostrophically balanced flow that develops due to a free surface perturbation, when the Coriolis parameter can be assumed constant

d) Barotropic Rossby radius of deformation corresponds to a length scale over which the waves on an equatorial thermocline propagate during one inertial period

Question X: Choose the correct statement: (1p)

a) The geostrophically balanced flow associated with a bumping (positive) sea level anomaly on the Northern Hemisphere will be clockwise

b) The geostrophically balanced flow associated with a bumping (positive) sea level anomaly on the Northern Hemisphere will be anticlockwise

c) The geostrophically balanced flow associated with a bumping (positive) sea level anomaly on the Northern Hemisphere will have a direction dependent on the latitude

d) The geostrophically balanced flow associated with a bumping (positive) sea level anomaly on the Northern Hemisphere will have a direction dependent on the longitude

Question X: Which of the below assumptions are NOT associated with quasigeostrophic (QG) approximation: (1p)

a) The material derivative can be expressed in terms of a geostrophic streamfunction

b) The variation of the Coriolis parameter around the reference latitude ($\frac{df}{dy}/f_o$) is small

c) The interface displacement is small compared to the depth of the fluid

d) The bottom topography is independent of time

Question X: The flow described by the 1-layer SWE system admits solutions for so-called "fast mode(s)" and "slow mode(s)". Choose a correct statement describing these "modes": (1p)

a) The "fast mode(s)" refer to the solutions that are retained under the QG approximation while the "slow modes" are not

b) The "fast modes" are the Poincare, Kelvin and Rossby waves with phase speed larger than $c = \sqrt{gH}$ while the "slow mode(s)" have lower phase speed than c

c) The "fast mode(s)" are all possible wave solutions of this system and the "slow mode" refer to the geostrophic flow solution

d) The "fast mode(s)" are the linear Poincare and Kelvin wave solutions and the "slow mode(s)" are the geostrophic flow and Rossby Wave solutions

Question X: The Rayleigh–Kuo stability criterion for the flow described by Eq. 3 states that: "if $\frac{dq_o}{dy}$ (background vorticity gradient) does not change sign anywhere in the interior of the domain, the flow is stable". Choose the correct statement: (1p)

a) This is a sufficient condition for instability

b) This is a sufficient condition for stability

c) This is a necessary condition for stability

d) Neither of a-c is correct

Question X: The two-layer QG model can be used to describe a phenomenon that neither one-layer barotropic QG nor reduced gravity rigid lid (1.5-layuer) model can. Which phenomenon is this? (1p)

a) Rossby waves

b) Conservation of potential vorticity

c) Barotropic instability

d) Baroclinic instability

Question X: The QG model cannot be used to study (1p)

a) Planetary Rossby waves

b) Poincare waves

c) Jet stream

d) Barotropic instability

Question X: The figure below shows longitude-time diagrams of an altimetric SSH measurement (left: raw data, right: band-passed filtered retaining periods 20-100 days). What kind of waves were measured? (1p)

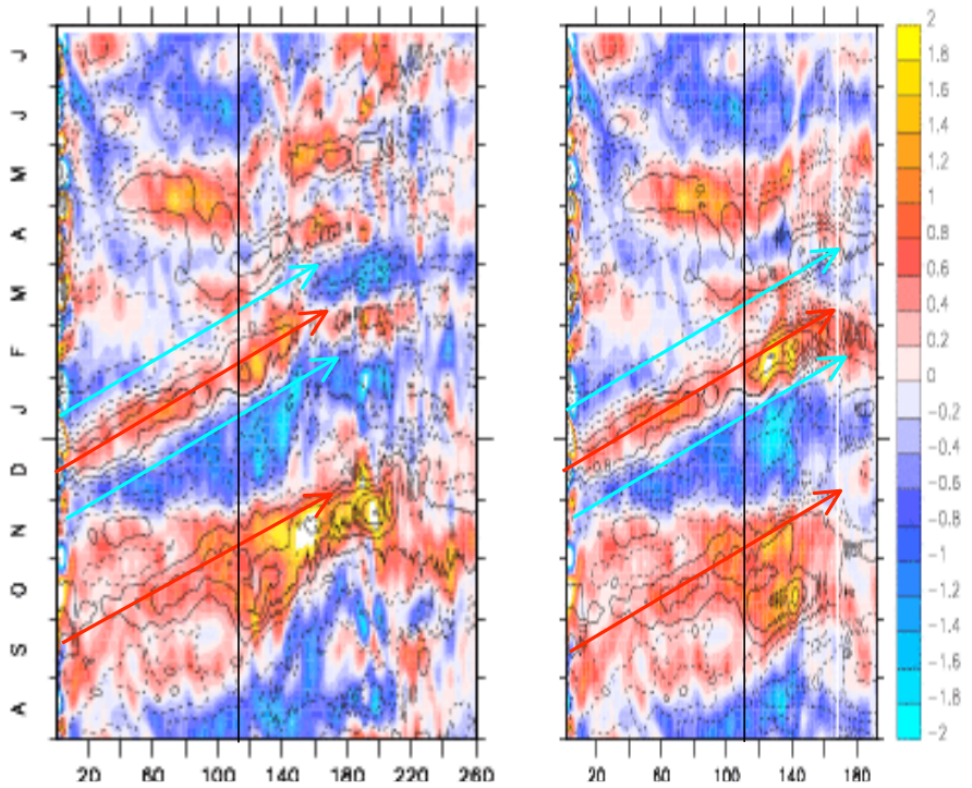


Figure 3. Climatology of the SSH intraseasonal anomalies (in cm), for observations (shaded areas) and the model (contour lines), along the northern track (left) and the southern track (right).

a) Barotropic Poincare waves

b) Coastal Kelvin waves at the American East Coast

c) Equatorial Kelvin waves propagating on the thermocline

d) Rossby waves

Question X: What are the correct sequence of symbols in the "Brcl instability" row describing the utility of GFD models to describe the baroclinic instability in the table shown below? (1p)

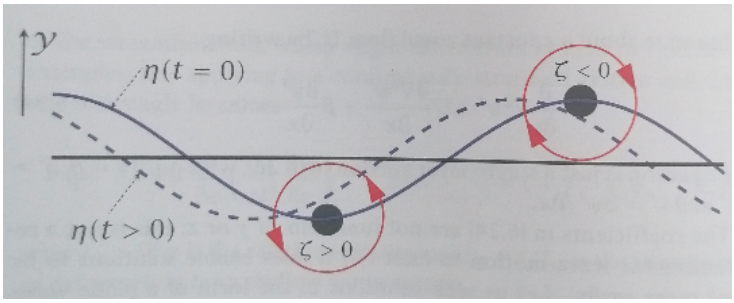
a) -, -, -, x

b) -, (x), -, x

c) x, -, -, x

d) -, (x), (x), x

Question X: The schematic below shows a mechanism explaining the propagation of: (1p)



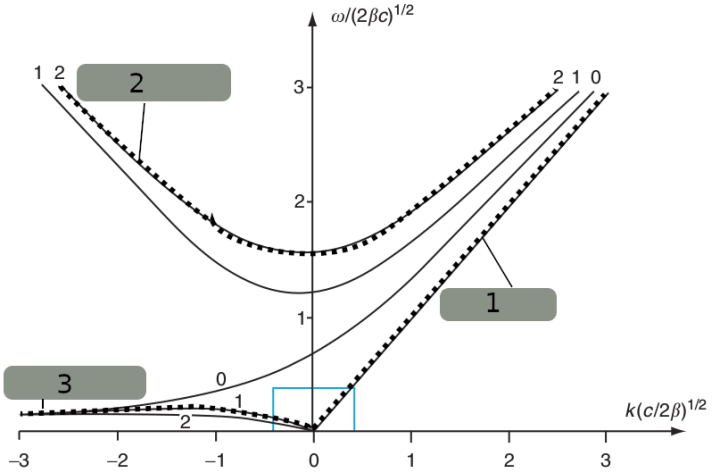
a) Poincare waves

b) Equatorial Kelvin waves

c) Coastal Kelvin waves

d) Rossby waves

Question X: What kind of waves are marked in the dispersion relation showed below?:(1p)



a) 1 = Poincare waves, 2 = Equatorial Rossby waves, 3 = Kelvin wave

b) 1 = Equatorial Rossby waves, 2 = Poincare waves, 3 = Kelvin wave

c) 1 = Equatorial Rossby waves, 2 = Kelvin wave, 3 = Poincare waves

d) 1 = Kelvin wave, 2 = Poincare waves, 3 = Equatorial Rossby waves