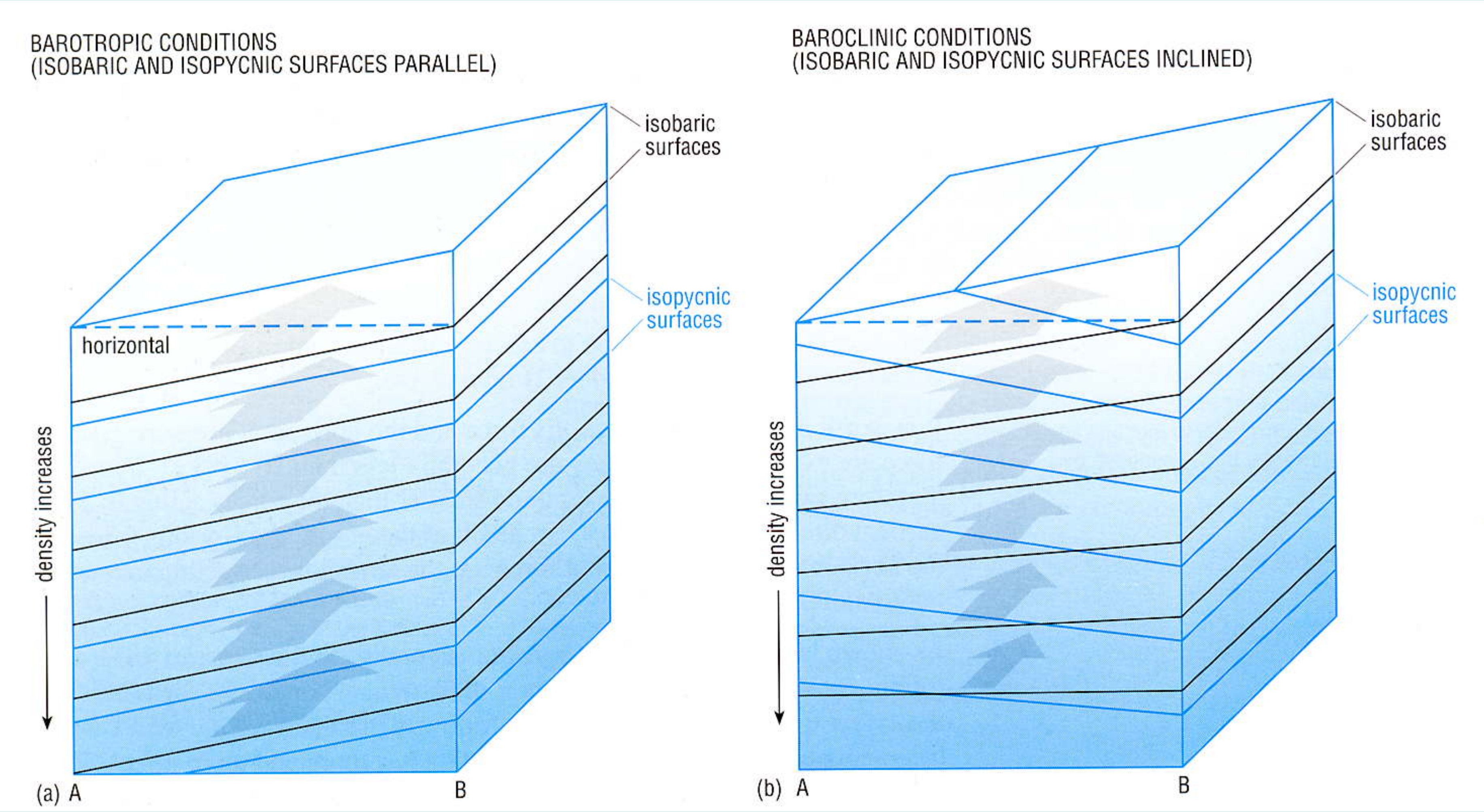
Balance de fuerzas: geostrofía

$$-fv = -(1/\rho)\frac{\partial p}{\partial x}$$

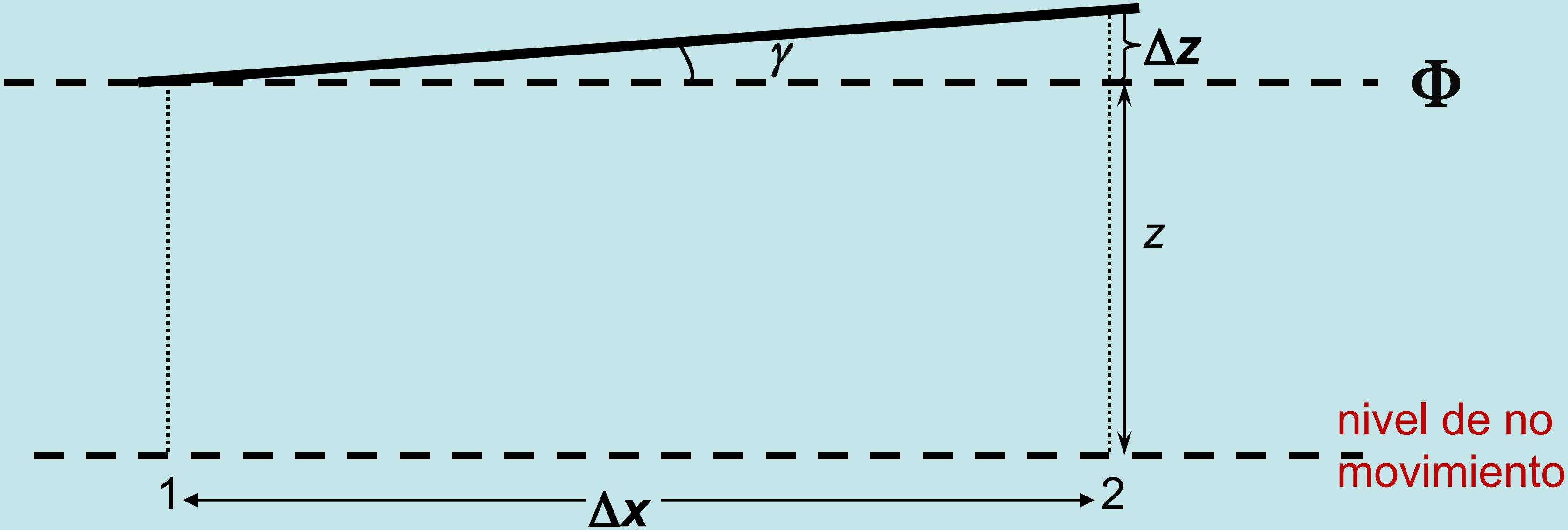
$$fu = -(1/\rho)\frac{\partial p}{\partial y}$$

Método para calcular (u,v) a partir de datos de T,S

Condiciones Barotrópicas y Baroclínicas



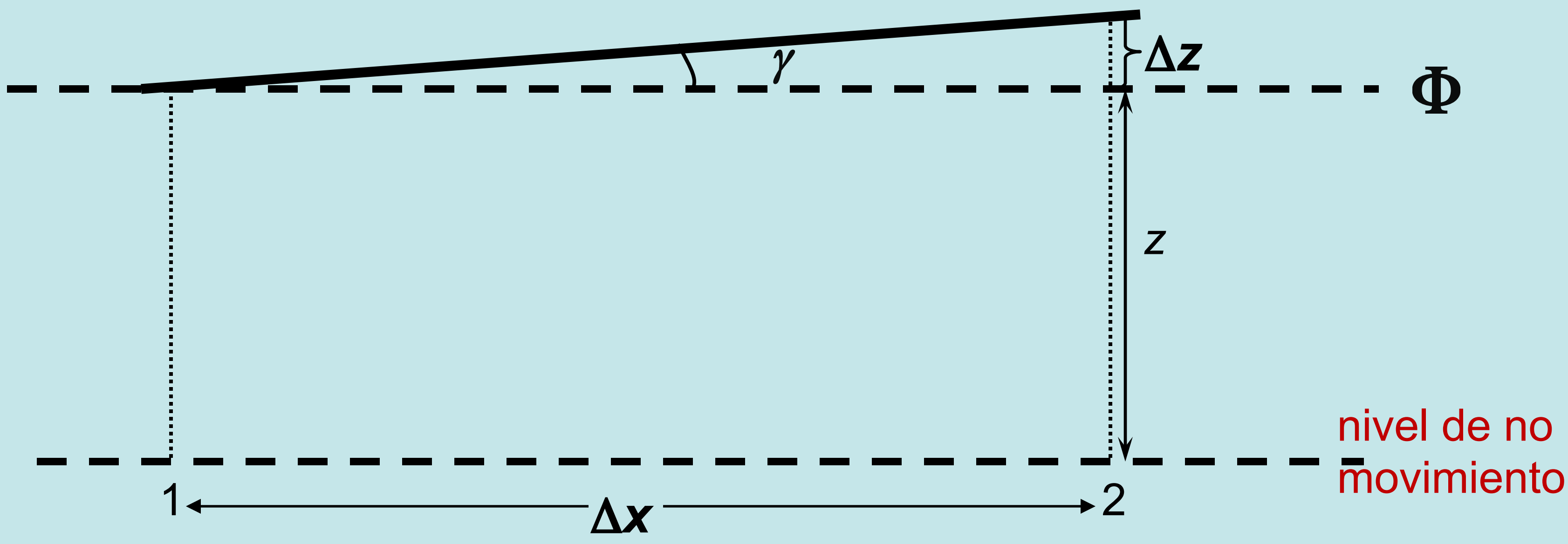
Caso barotrópico (ρ = constante)



$$P_1 = -\rho g z_1 \qquad\qquad P_2 = -\rho g z_2$$

$$\frac{P_2 - P_1}{\Delta x} = \frac{\Delta p}{\Delta x} = -\rho g \frac{\Delta z}{\Delta x}$$

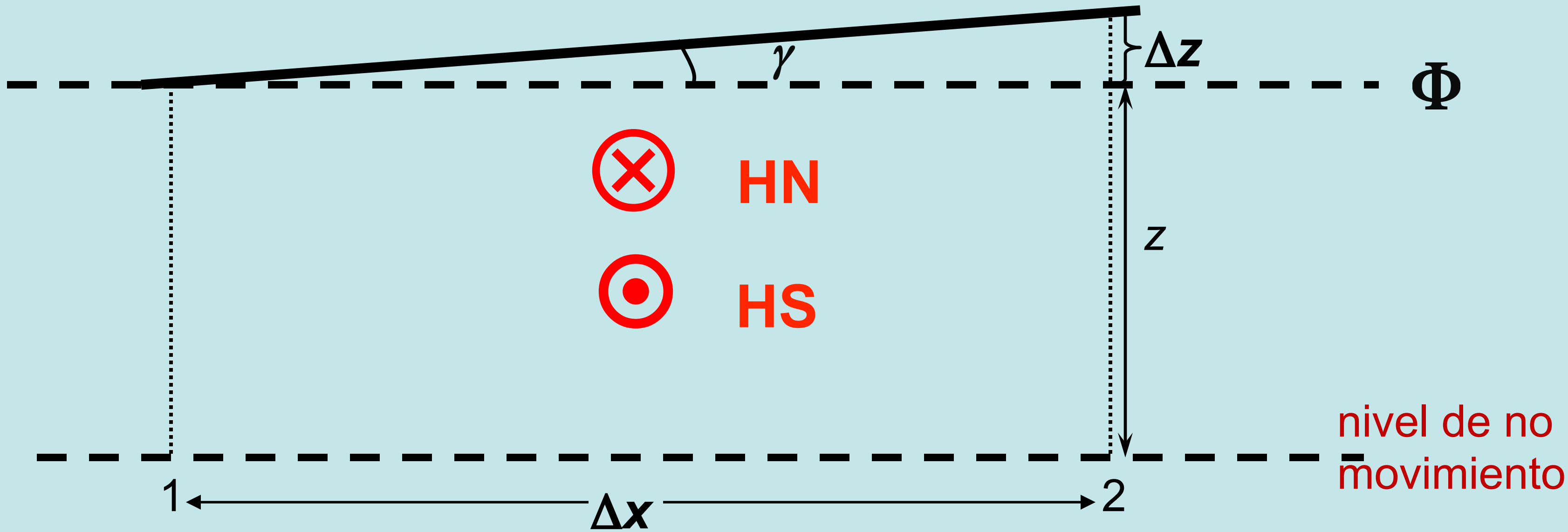
esta es la fuerza del gradiente de presión por unidad de volumen (N/m^3)



La fuerza del gradiente de presión por unidad de masa es:

$$\frac{F_{GPH}}{\rho} = \frac{1}{\rho}\left[-\rho g \frac{\Delta z}{\Delta x} \right]$$

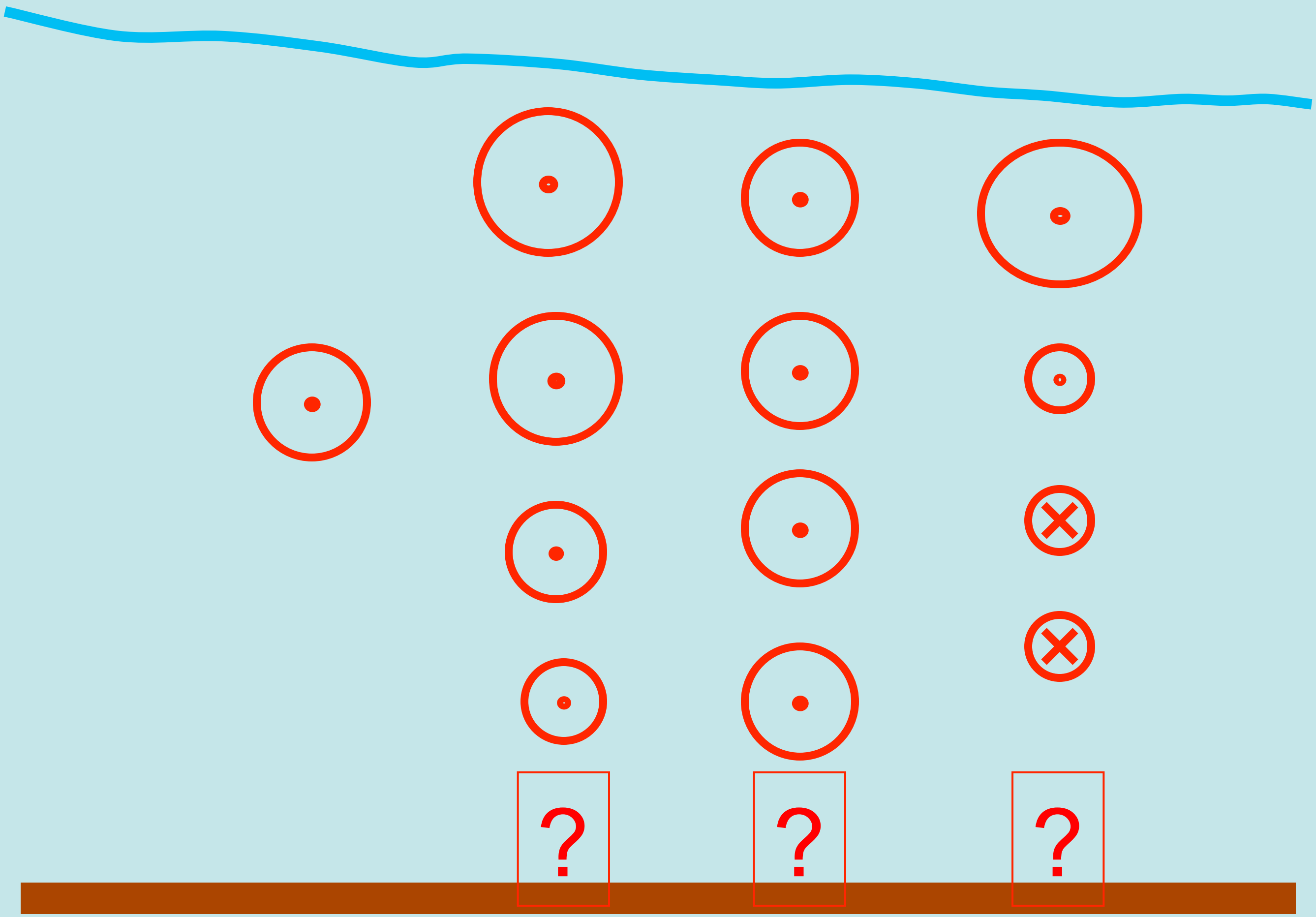
$$= -g \frac{\Delta z}{\Delta x}$$



El balance geostrófico está dado por:

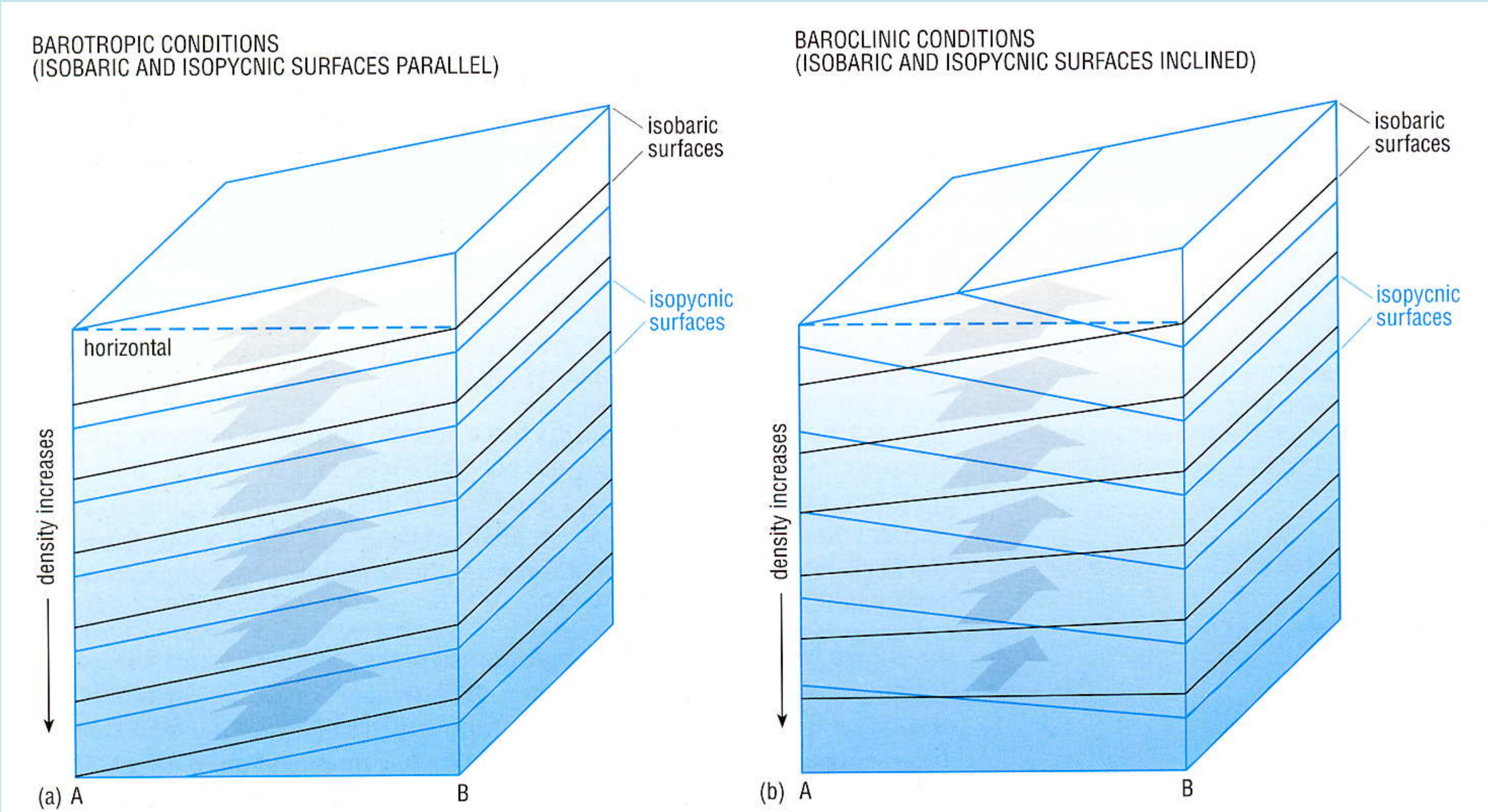
$$fU_h = -g\frac{\Delta z}{\Delta x} = -g\tan\gamma$$

El balance geostrófico ofrece una aproximación para la corriente promedio



que sucede cuando hay estratificación y la presión depende de densidad ?

Condiciones Barotrópicas y Baroclínicas



$$\frac{\partial p}{\partial x} = \rho f v; \quad \frac{\partial p}{\partial y} = -\rho f u; \quad \frac{\partial p}{\partial z} = -\rho g$$

x ***y*** ***z***

$$u = -\frac{1}{\rho f} \frac{\partial p}{\partial y}$$

$$v = \frac{1}{\rho f} \frac{\partial p}{\partial x}$$

$$p = p_0 + \int_{-h}^{\eta} g(\varphi, z) \rho(z) dz$$

$$u = -\frac{1}{\rho f}\ \frac{\partial p}{\partial y}$$ 1

$$v = \frac{1}{\rho f}\ \frac{\partial p}{\partial x}$$

$$p = p_0 + \int_{-h}^{\eta} g(\varphi, z)\rho(z)\,dz$$ 2

Sustituyendo (2) en (1) se obtiene:

$$u = -\frac{1}{\rho f}\frac{\partial}{\partial y}\int_{-h}^{0} g(\varphi, z)\rho(z)\,dz - \frac{g}{f}\frac{\partial \eta}{\partial y}$$

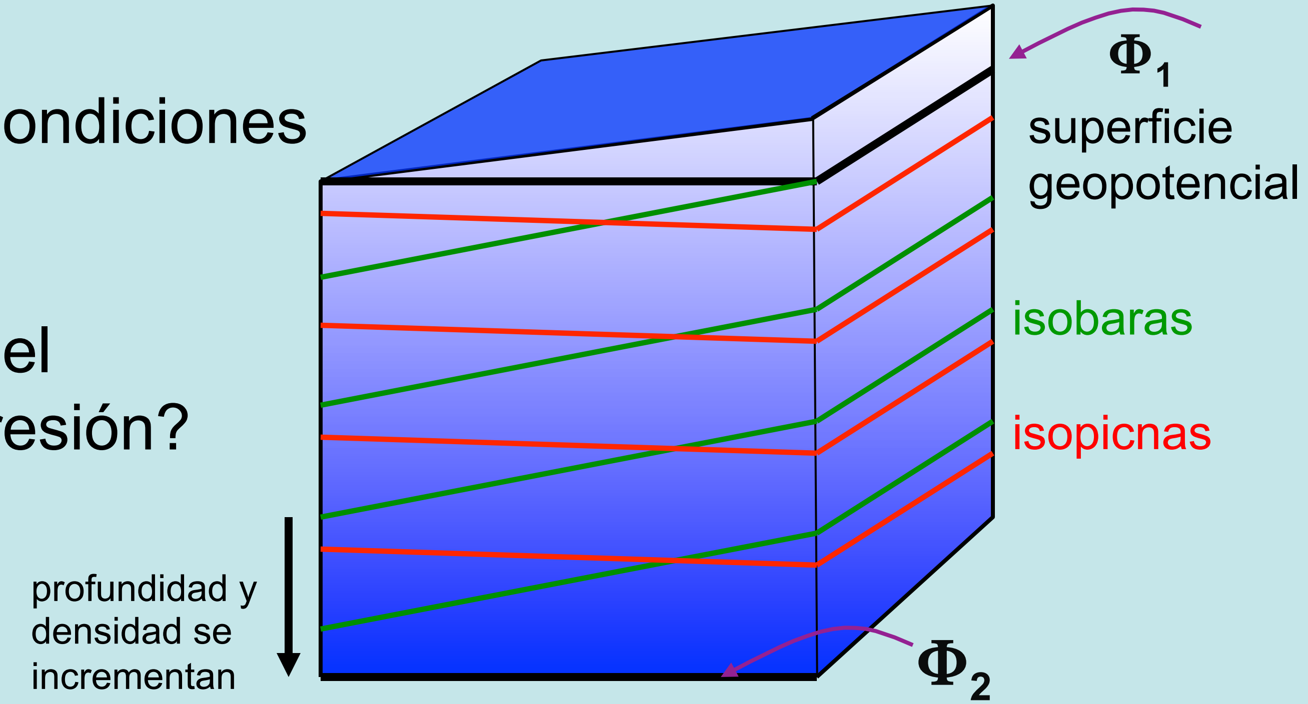
$$\boxed{u = -\frac{1}{\rho f}\frac{\partial}{\partial y}\int_{-h}^{0} g(\varphi, z)\rho(z)\,dz - u_S}$$

$$v = -\frac{1}{\rho f}\frac{\partial}{\partial x}\int_{-h}^{0} g(\varphi, z)\rho(z)\,dz - \frac{g}{f}\frac{\partial \eta}{\partial x}$$

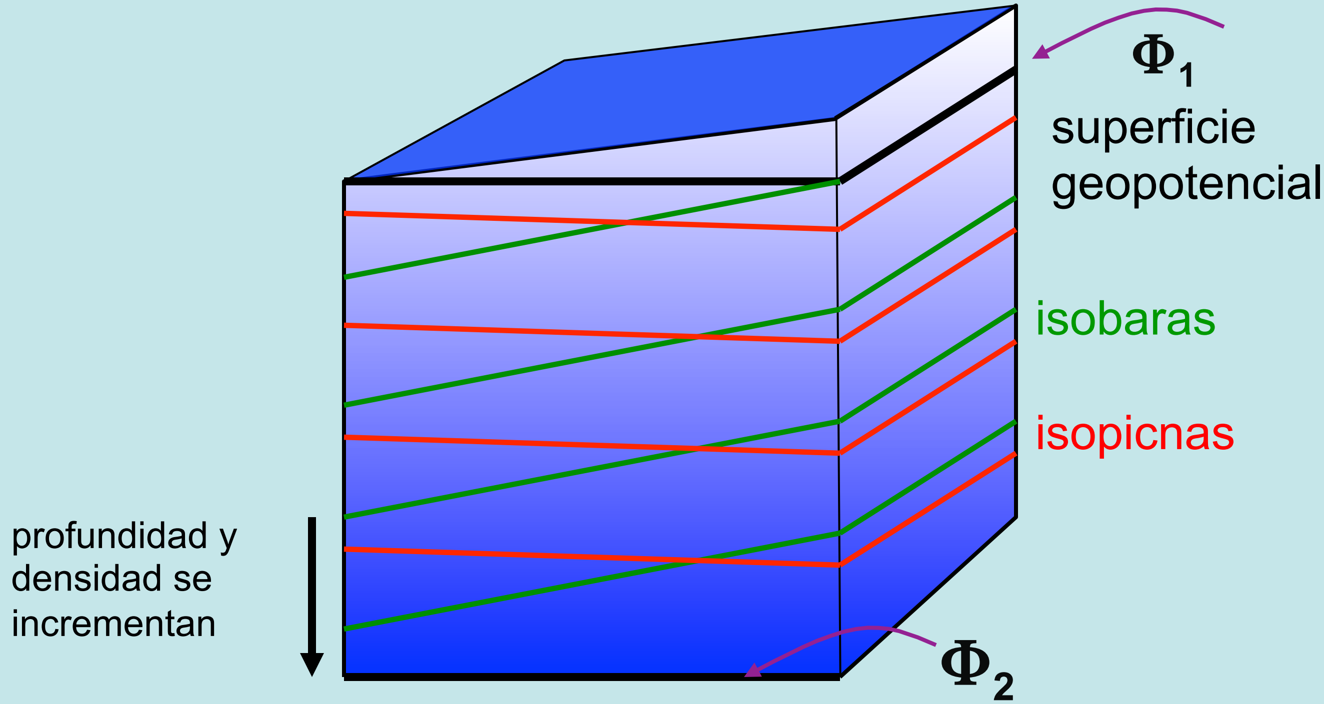
$$\boxed{v = -\frac{1}{\rho f}\frac{\partial}{\partial x}\int_{-h}^{0} g(\varphi, z)\rho(z)\,dz - v_S}$$

Diagrama de Condiciones Baroclínicas

Como se mide el gradiente de presión?



Definiciones:
Distancia Geopotencial – es la distancia entre dos superficies isobáricas localizadas en z_1 y z_2



El trabajo que se requiere para llevar un volumen de agua con masa ***M*** una distancia ***dz*** en contra de la fuerza de gravedad es *Mgdz*

El cambio de geopotencial dΦ es la energía potencial por unidad de masa que gana ese volumen de agua, o:

$$d\Phi = g\,dz\left(J/kg = m^2/s^2\right) = -\alpha dp$$

$$d\Phi = g\,dz = -\alpha\,dp$$

Es necesario calcular ***dΦ*** entre z_1 y z_2 para calcular los gradientes de presión baroclínicos

$$\int_1^2 d\Phi = \int_1^2 g\,dz = \int_1^2 \frac{dp}{\rho} = \int_1^2 \alpha\,dp$$

Con: $$\frac{1}{\rho} = \alpha = \alpha_{35,0,p} + \delta$$

$$\int_1^2 d\Phi = \int_1^2 g\,dz = \int_1^2 \frac{dp}{\rho} = \int_1^2 \alpha\,dp$$

con $\alpha = \alpha_{35,0,p} + \delta$

anomalía geopotencial

$$\Delta\Phi$$

$$\Phi_2 - \Phi_1 = g\left(z_2 - z_1\right) = \int_1^2 \alpha_{35,0,p}\,dp - \int_1^2 \delta\,dp$$

$$\Delta\Phi_{std}$$

distancia geopotencial estándar

Distancia geopotencial entre z_1 y z_2 donde las presiones son p_1 y p_2

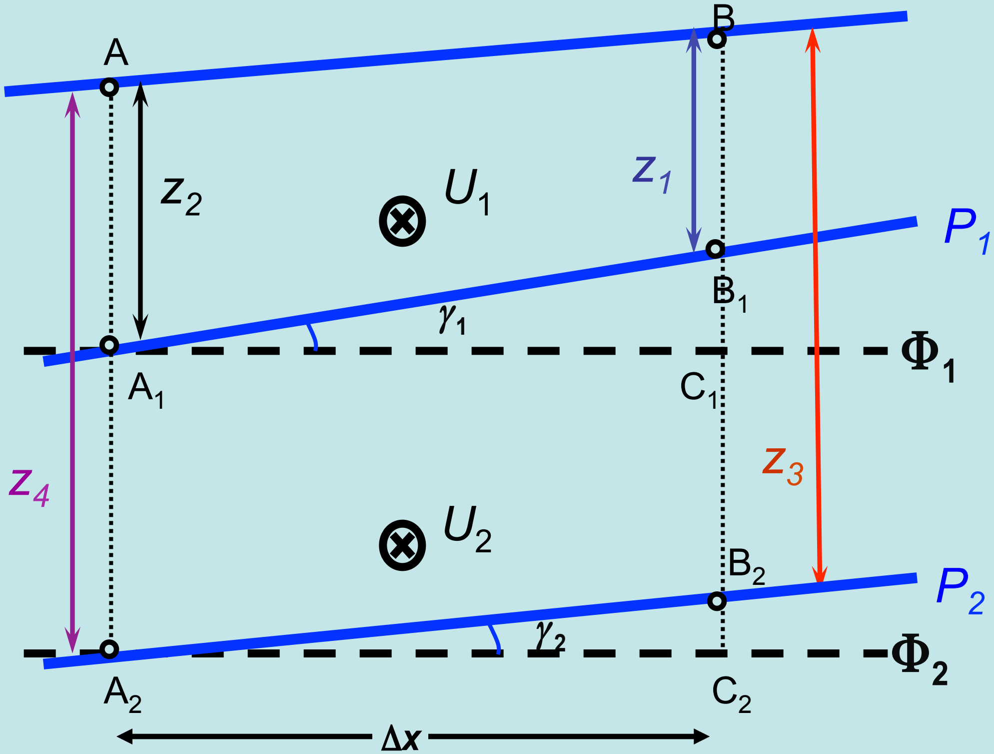
$$\Phi_2 - \Phi_1 = g\left(z_2 - z_1\right) = \int_1^2 \alpha_{35,0,p}\, dp - \int_1^2 \delta\, dp$$

Unidades son m^2 / s^2 o energía por unidad de masa (J/kg)

$$\text{si } z_2 - z_1 = 1\,\text{m} \quad \Rightarrow \quad \Phi_2 - \Phi_1 = 9.8\; J/kg \approx 1\,\text{m dinámico}$$

$$= 10\; J/kg = 10\;\text{m}^2/\text{s}^2$$

La Topografía Dinámica se refiere a
Distancias Geopotenciales



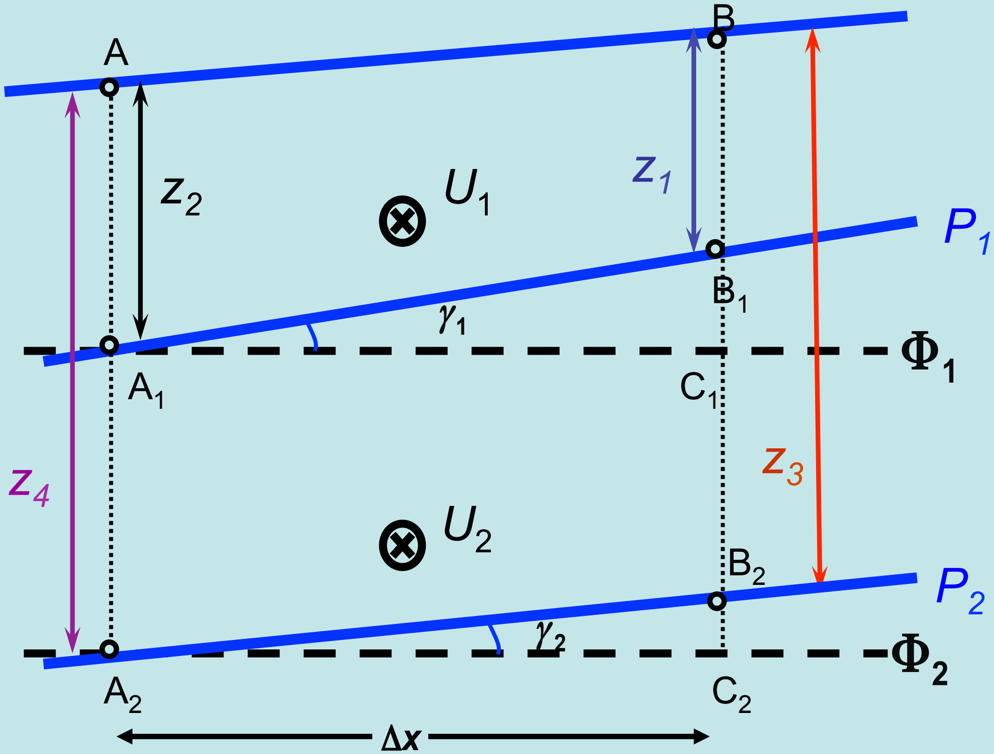
$$fU_1 = g\tan g_1$$

$$fU_2 = g\tan\gamma_2$$

$$f(U_1 - U_2) = g(\tan\gamma_1 - \tan\gamma_2)$$

$$f(U_1 - U_2) = g\left[\frac{B_1C_1}{A_1C_1} - \frac{B_2C_2}{A_2C_2}\right] = \frac{g}{\Delta x}\left[B_1C_1 - B_2C_2\right]$$

$$= \frac{g}{\Delta x}\left[B_1B_2 - C_1C_2\right] = \frac{g}{\Delta x}\left[B_1B_2 - A_1A_2\right]$$



$$fU_1 = g\tan\gamma_1$$

$$fU_2 = g\tan\gamma_2$$

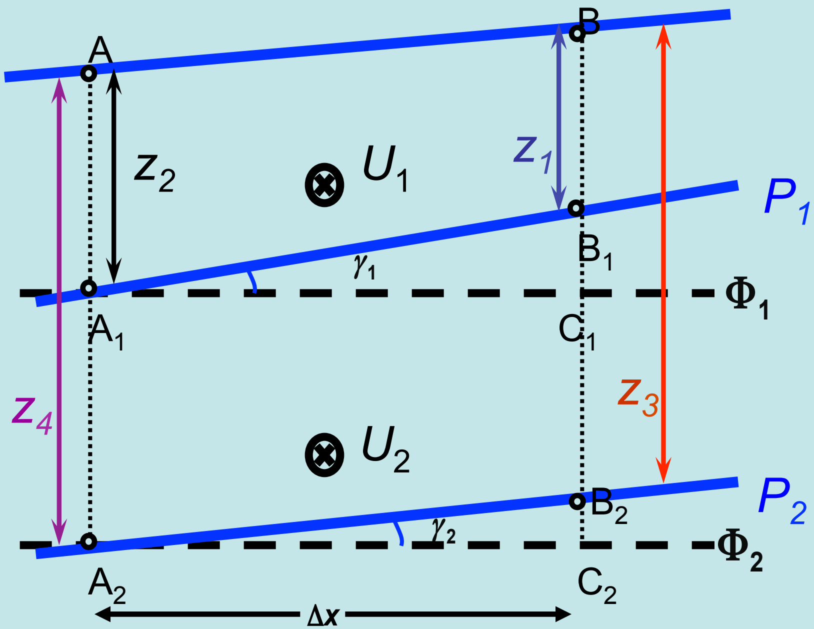
$$f(U_1 - U_2) = g(\tan\gamma_1 - \tan\gamma_2)$$

$$f(U_1 - U_2) = \frac{g}{\Delta x}\left[B_1B_2 - A_1A_2\right]$$

$$f(U_1 - U_2) = \frac{g}{\Delta x}\left[(z_1 - z_3) - (z_2 - z_4)\right]$$

de la ecuación hidrostática : $g\,dz = -\alpha\,dp$

$$\int_{B_1}^{B_2} g\,dz = g(z_3 - z_1) = -\int_{P_1}^{P_2}\alpha_B\,dp = -\int_{P_1}^{P_2}\alpha_{35,0,p}\,dp - \int_{P_1}^{P_2}\delta_B\,dp$$



$$f(U_1 - U_2) = \frac{g}{\Delta x}\left[(z_1 - z_3) - (z_2 - z_4)\right]$$

$$\int_{B_1}^{B_2} g\,dz = g(z_3 - z_1) = -\int_{P_1}^{P_2} \alpha_{35,0,p}\,dp - \int_{P_1}^{P_2} \delta_B\,dp$$

$$\int_{A_1}^{A_2} g\,dz = g(z_4 - z_2) = -\int_{P_1}^{P_2} \alpha_{35,0,p}\,dp - \int_{P_1}^{P_2} \delta_A\,dp$$

$$g(\tan\gamma_1 - \tan\gamma_2) = \frac{1}{\Delta x}\left\{\int_{P_1}^{P_2} \delta_B\,dp - \int_{P_1}^{P_2} \delta_A\,dp\right\}$$

$$\boxed{(U_1 - U_2) = \frac{1}{f\,\Delta x}\left\{\int_{P_1}^{P_2} \delta_B\,dp - \int_{P_1}^{P_2} \delta_A\,dp\right\}}$$

$$\boxed{(U_1 - U_2) = \frac{1}{f\,\Delta x}\left\{\Delta\Phi_B - \Delta\Phi_A\right\}}$$

Anomalías de geopotencial

Estación A: 41°55'N, 50°09'W m^2/s^2

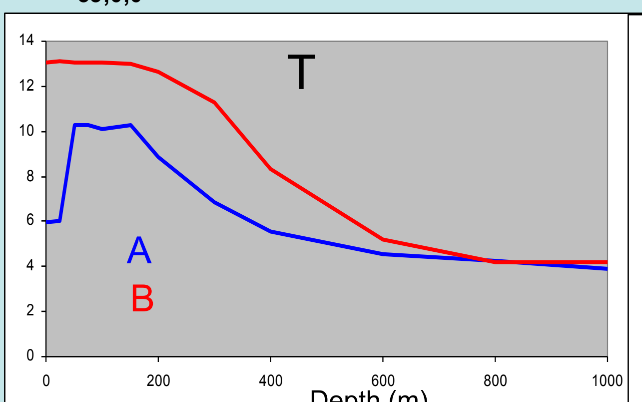
Depth (m)	T°C	S	σ_t kg/m^3	δ_A m^3/kg	$\bar{\delta}$ X10^{-8}	$\bar{\delta}\times\Delta p$ 10^4 Pa	$\sum\bar{\delta}\times\Delta p = \Delta\Phi_A$
0	5.99	33.71	26.53	148			6.638
25	6.00	33.78	26.61	144	146	0.365	6.273
50	10.30	34.86	26.81	126	135	0.338	5.935
75	10.30	34.88	26.83	125	126	0.315	5.620
100	10.10	34.92	26.89	119	122	0.305	5.315
150	10.25	35.17	27.06	104	112	0.560	4.755
200	8.85	35.03	27.19	93	99	0.455	4.300
300	6.85	34.93	27.41	73	83	0.830	3.470
400	5.55	34.93	27.58	57	65	0.650	2.820
600	4.55	34.95	27.71	46	52	1.040	1.780
800	4.25	34.95	27.74	45	45	0.900	0.880
1000	3.90	34.95	27.78	43	44	0.880	0

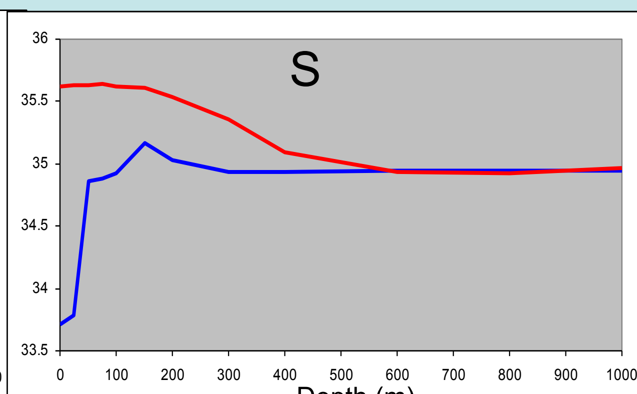
Estación B: 41°28'N, 50°09'W m^2/s^2

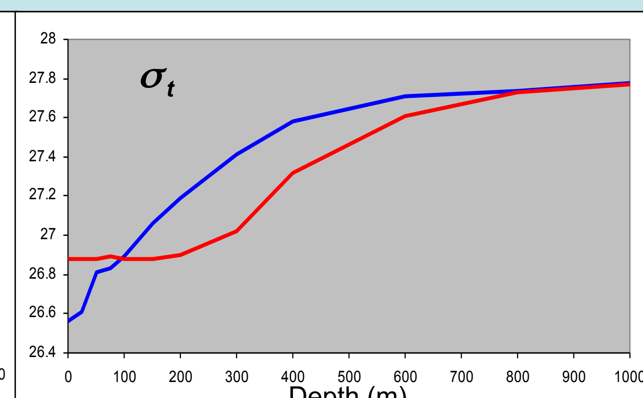
Depth (m)	T°C	S	σ_t kg/m^3	δ_B m^3/kg	$\bar{\delta}$ X10^{-8}	$\bar{\delta}\times\Delta p$ 10^4 Pa	$\sum\bar{\delta}\times\Delta p = \Delta\Phi_B$
0	13.04	35.62	26.88	118			7.894
25	13.09	35.63	26.88	119	119	0.298	7.596
50	13.07	35.63	26.88	119	119	0.298	7.298
75	13.05	35.64	26.89	119	119	0.298	7.000
100	13.05	35.62	26.88	121	120	0.300	6.700
150	13.00	35.61	26.88	122	122	0.610	6.090
200	12.65	35.54	26.90	121	122	0.610	5.480
300	11.30	35.36	27.02	112	117	1.170	4.310
400	8.30	35.09	27.32	83	98	0.980	3.330
600	5.20	34.93	27.61	57	70	1.400	1.930
800	4.20	34.92	27.73	46	52	1.030	0.900
1000	4.20	34.97	27.77	44	45	0.900	0

$\sigma_{35,0,0}$ = **28.106**

1000 m es el NMV; recordar que 1 db = 10^4 Pa

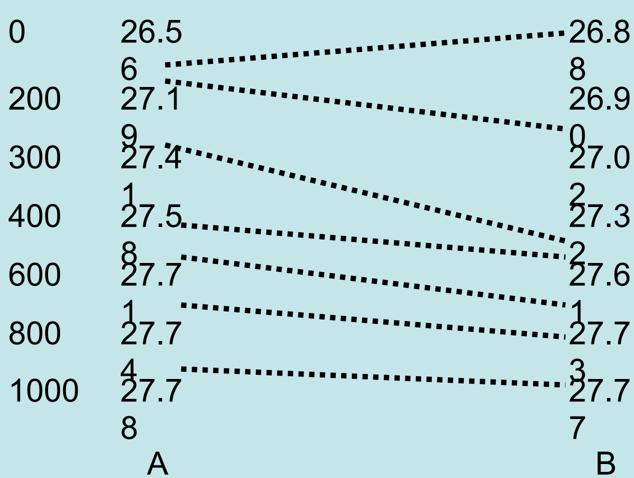






Anomalías de geopotencial y la velocidad relativa entre A y B

PROF (m)	$\Delta\Phi_B$ m²/s²	$\Delta\Phi_A$ m²/s²	$\Delta\Phi_B - \Delta\Phi_A$ m²/s²	V_{rel} m/s
0	7.894	6.638	1.256	0.26
25	7.596	6.273	1.323	0.27
50	7.298	5.935	1.363	0.28
75	7.000	5.620	1.380	0.29
100	6.700	5.315	1.385	0.29
150	6.090	4.755	1.335	0.28
200	5.480	4.300	1.180	0.24
300	4.310	3.470	0.840	0.17
400	3.330	2.820	0.510	0.11
600	1.930	1.780	0.150	0.03
800	0.900	0.880	0.020	0.005
1000	0	0	0	0

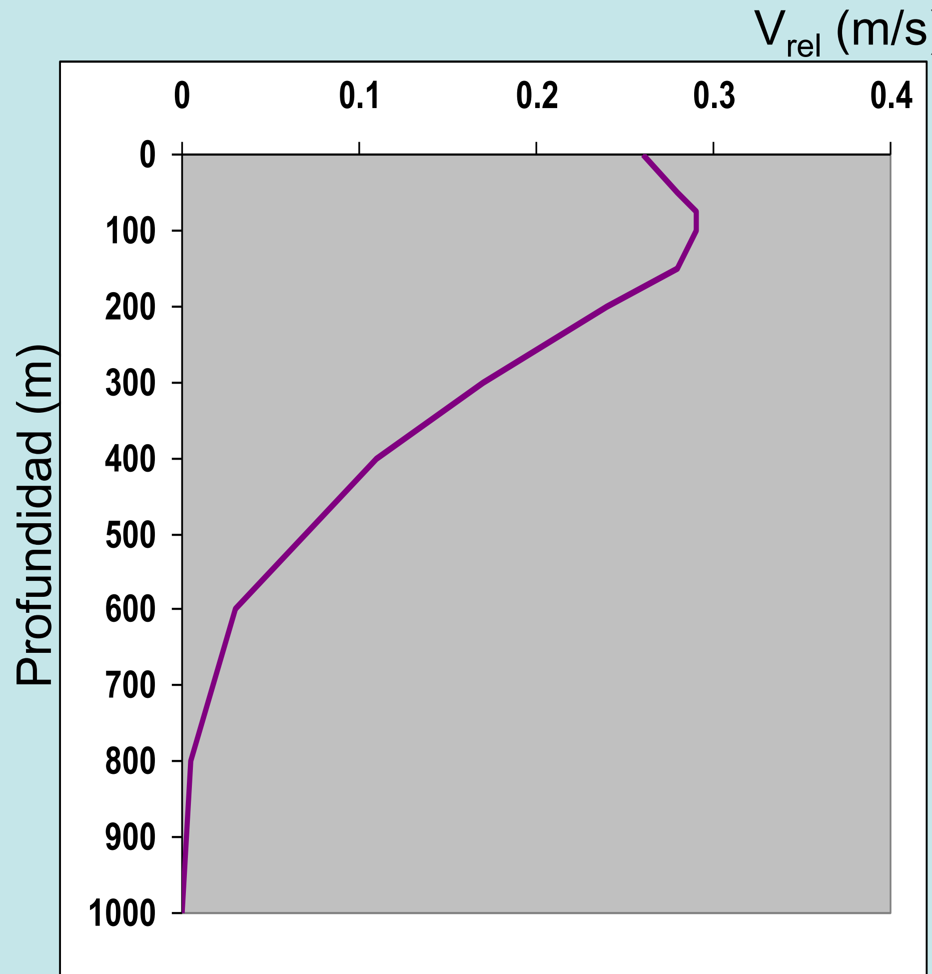


$$(U_1 - U_2) = \frac{1}{f\,\Delta x}\{\Delta\Phi_B - \Delta\Phi_A\}$$

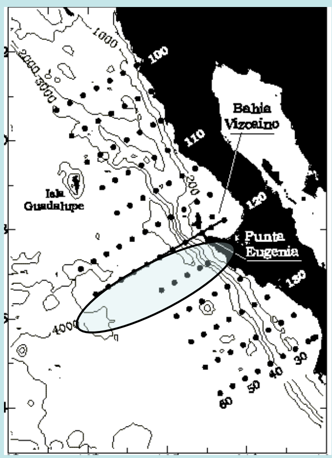
Δx = 27’ o 27 millas náuticas

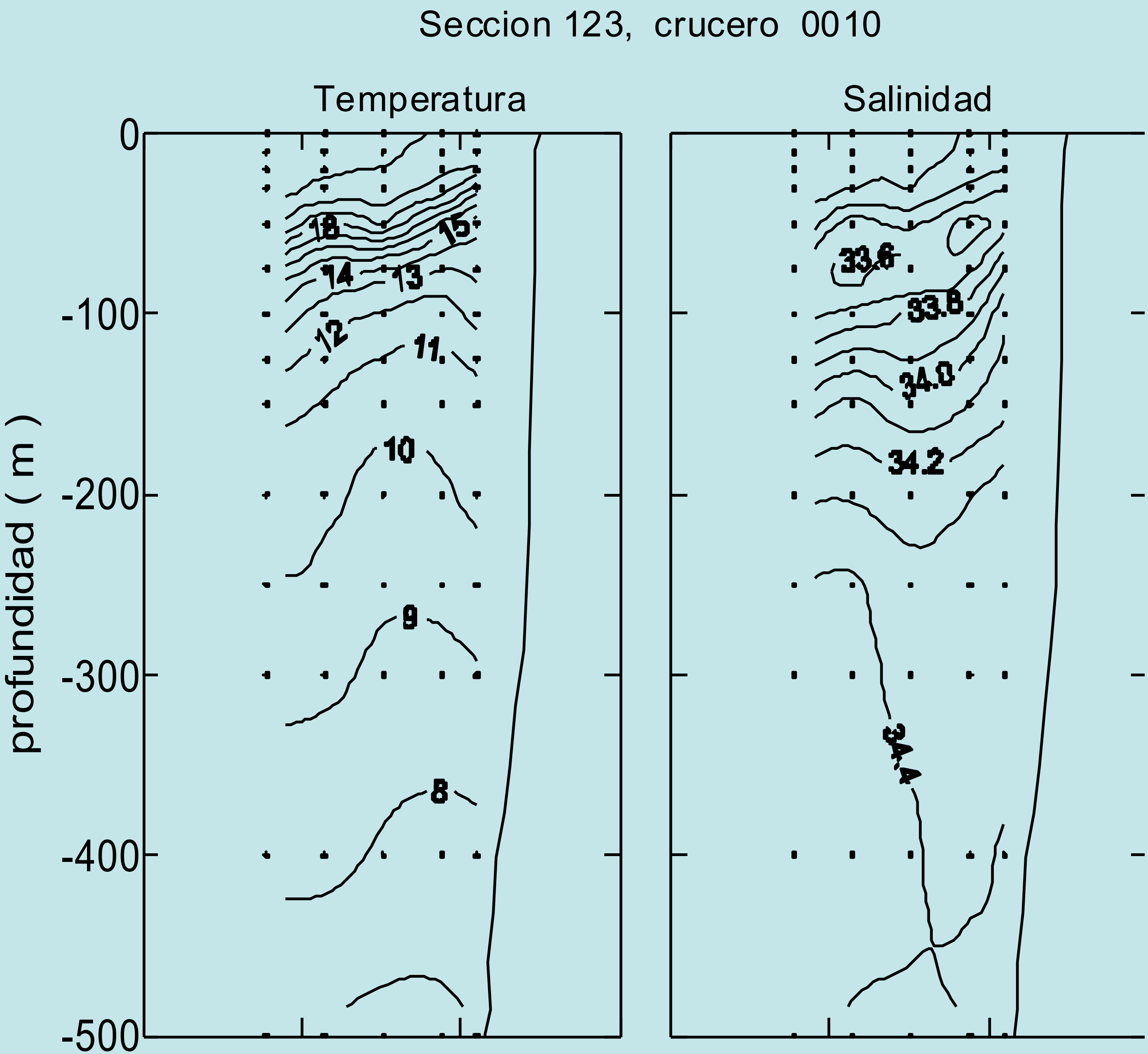
27 m.n. x 1852 m/m.n. = 50,000 m

$f = 9.7\text{x}10^{-5}\ s^{-1}$

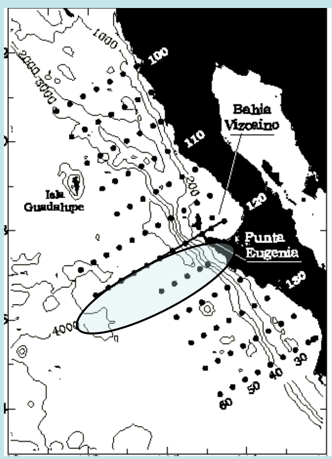


EJEMPLO IMECOCAL

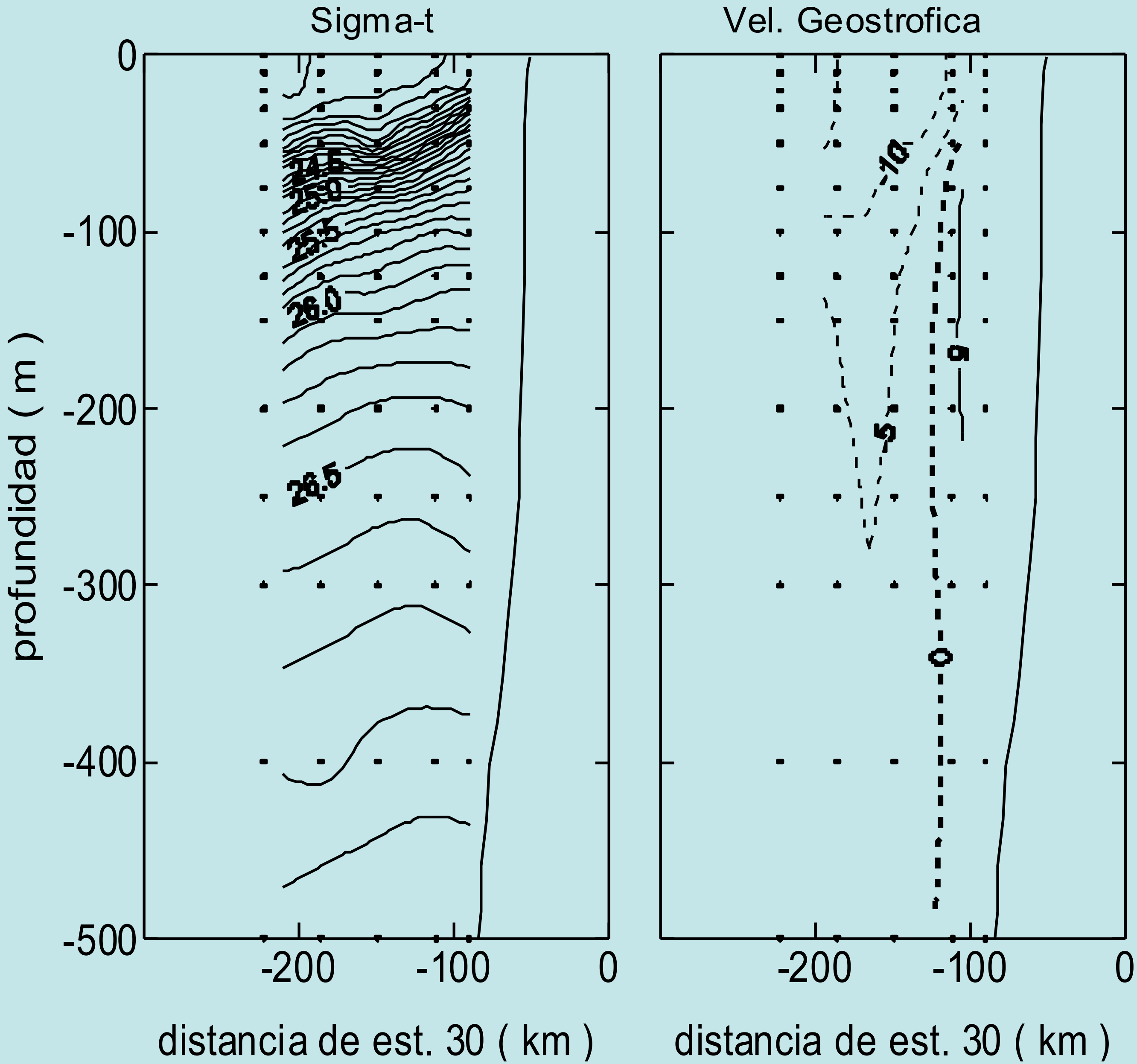


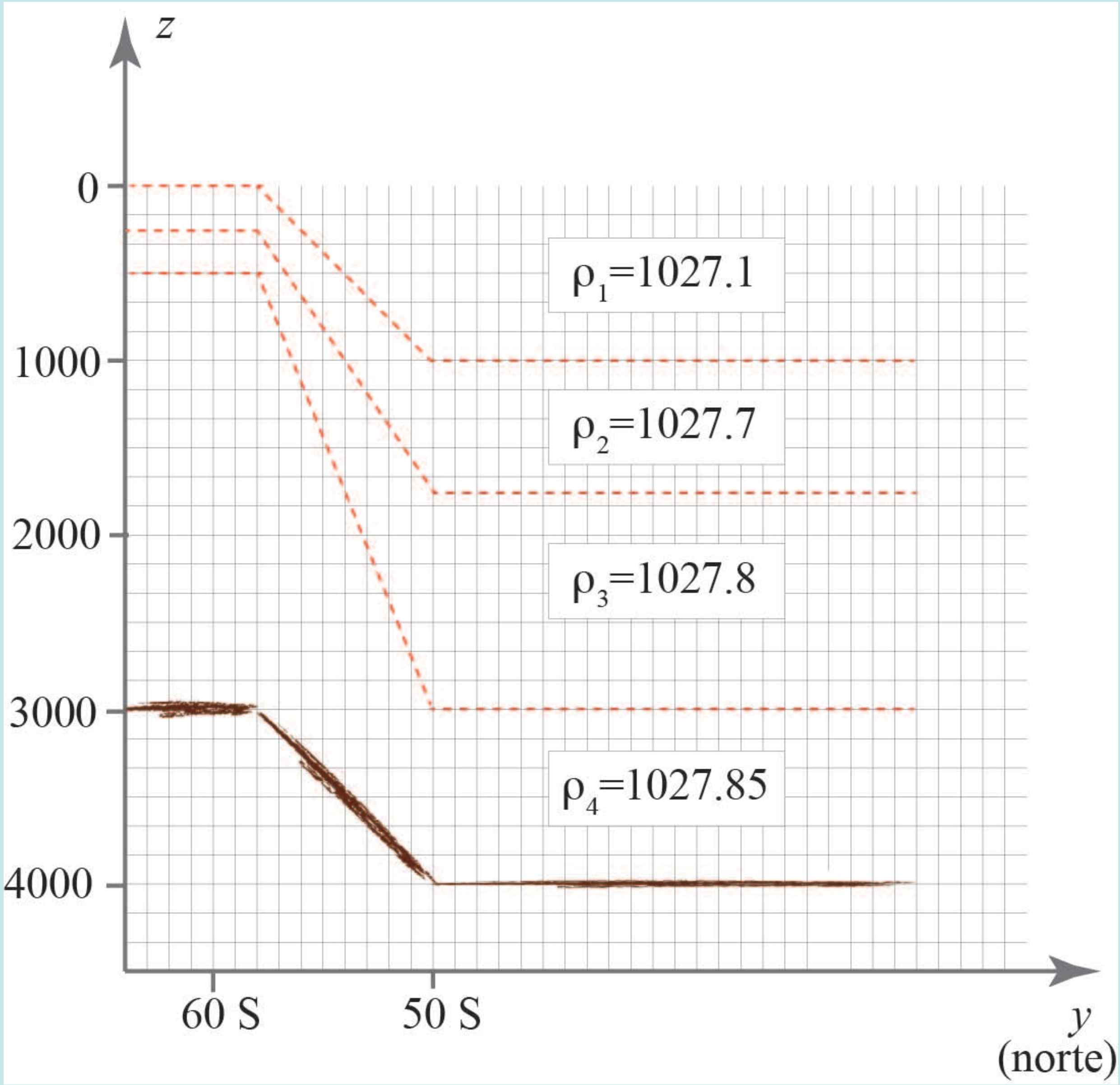


EJEMPLO IMECOCAL



Seccion 123, crucero 0010





$$f\,(u_1 - u_2) = g_1^{'} \tan\gamma_1$$

$$f\,(u_1 - u_2) = g_1^{'} \tan\gamma_1$$

$$f\,(u_1 - u_2) = g_1^{'} \tan\gamma_1$$

$$g_1^{'} = \frac{\rho_2 - \rho_1}{\rho_1} g$$

$$\tan\gamma = \frac{\Delta z}{\Delta y}$$