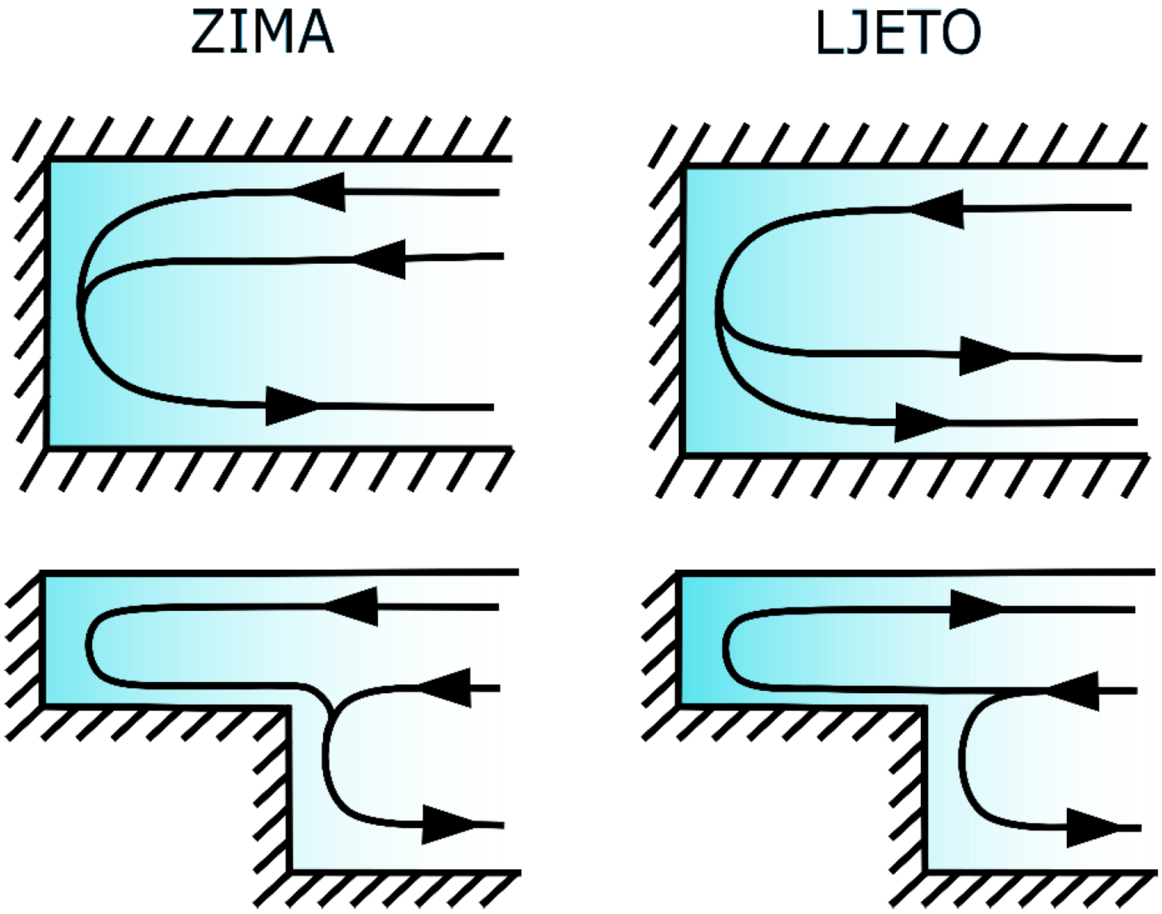
Četvrto predavanje
(1. travnja 2022.)

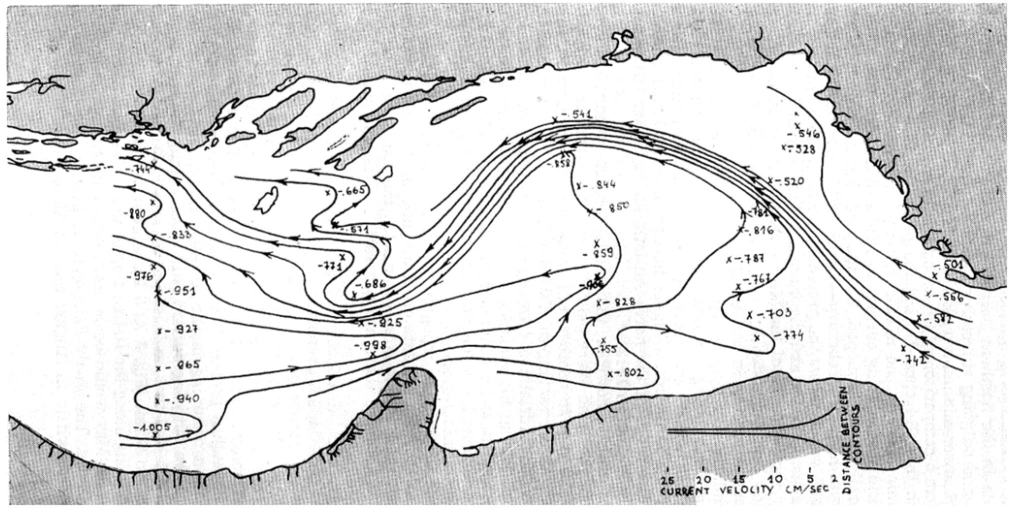
2. Vjetrovno strujanje u okrajnjim morima

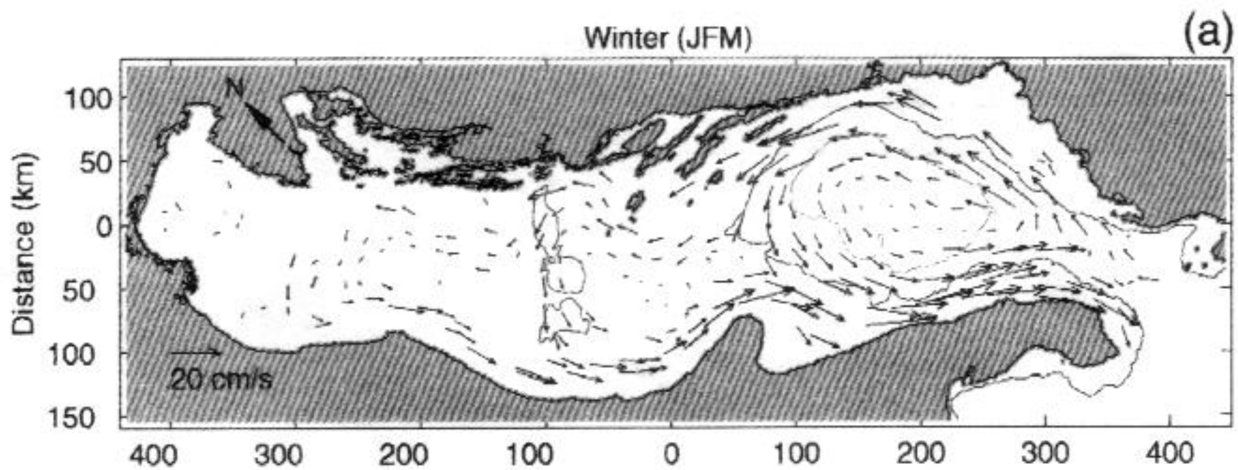
2.1. Uvod

Jadran – shematski prikaz rezidualne cirkulacije



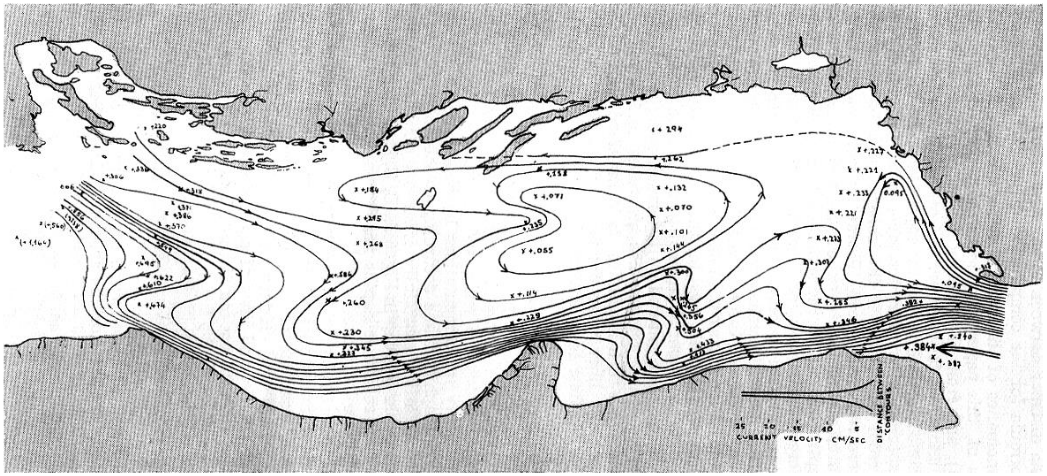
Jadran – zima

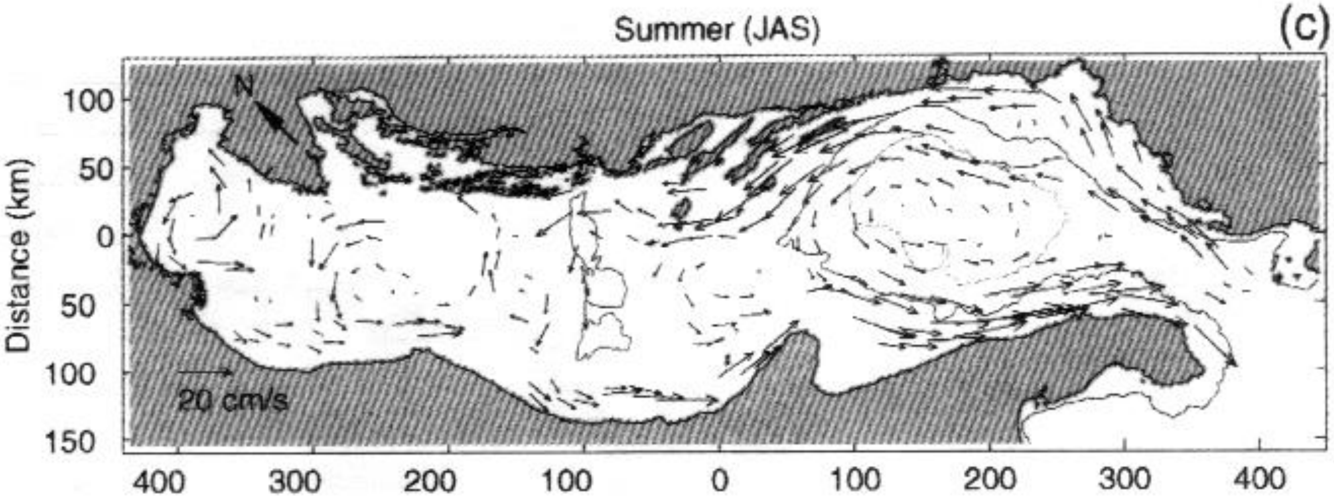




Zore, 1956.
Poulain, 2001.

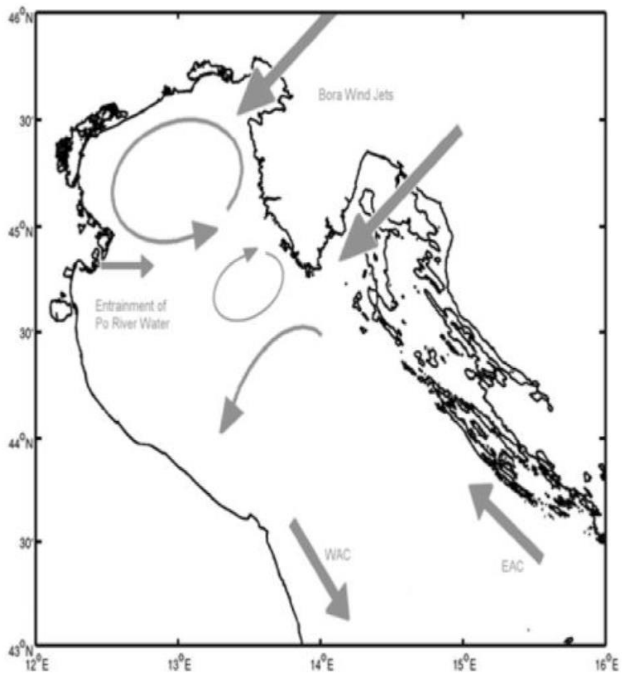
Jadran – ljeto



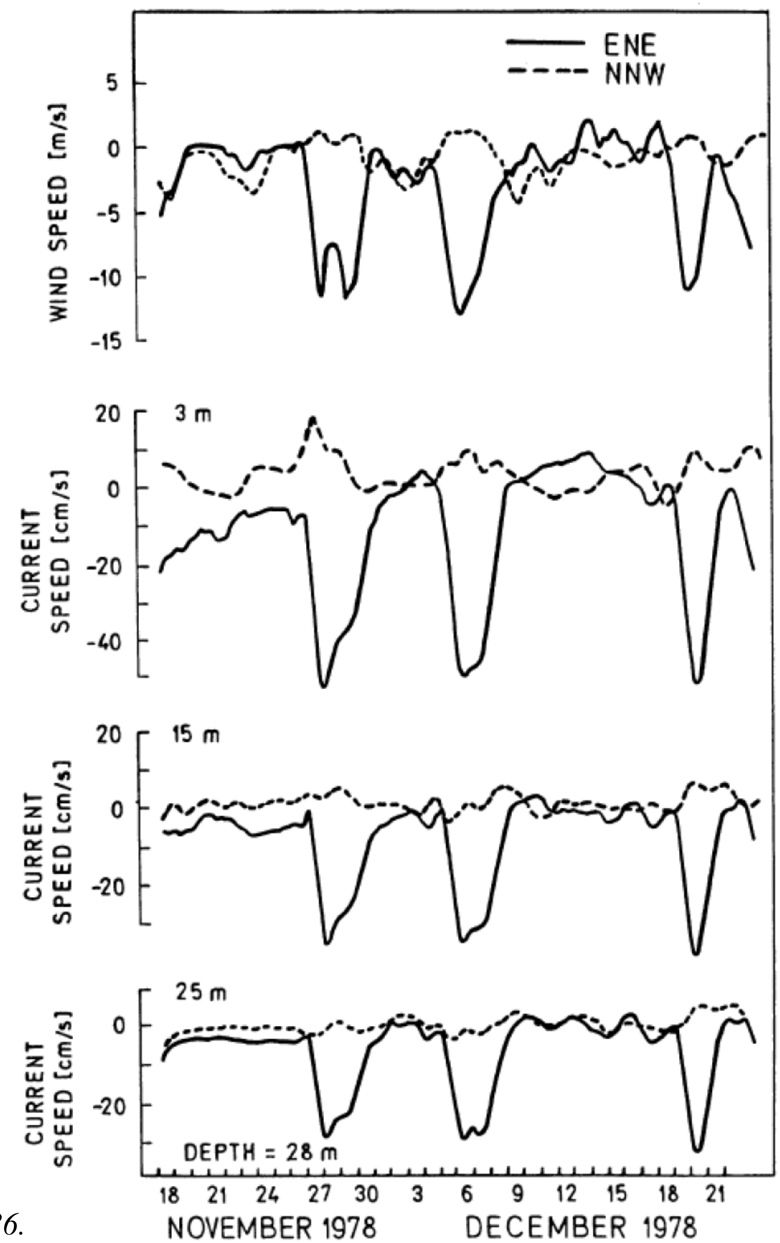


Zore, 1956.
Poulain, 2001.

Jadran – vjetrovno strujanje

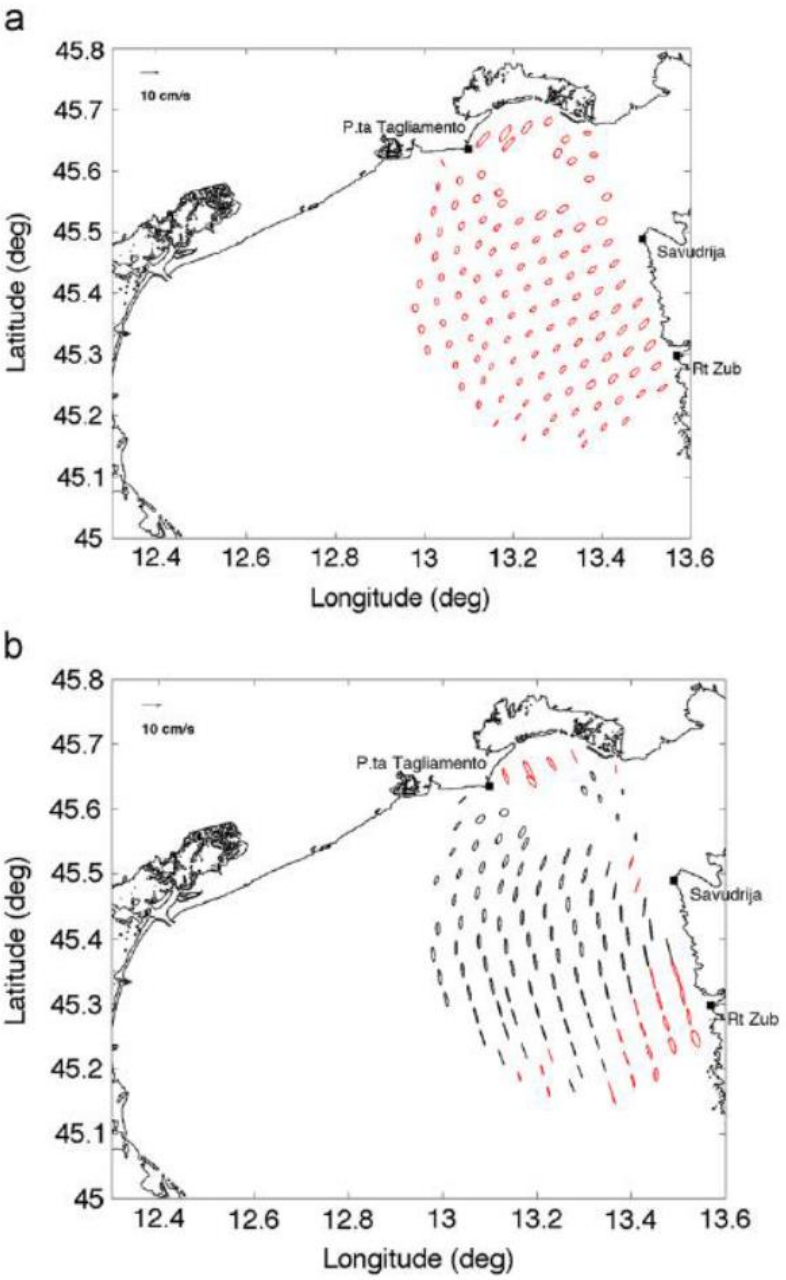


Jeffries, Lee, 2007.



Orlić et al., 1986.

Jadran – plimne struje
(a: K1, b: M2;
crveno: satna rotacija,
crno: protusatna rotacija)



Cosoli et al., 2012.

2.2. Model nizozemske škole (M. P. H. Weenink, 1958, i dr.)

Početne jednadžbe

$$\frac{1}{\rho}\frac{\partial p}{\partial x} = fv + \frac{1}{\rho}\frac{\partial}{\partial z}\left(A\frac{\partial u}{\partial z}\right)$$

$$\frac{1}{\rho}\frac{\partial p}{\partial y} = -fu + \frac{1}{\rho}\frac{\partial}{\partial z}\left(A\frac{\partial v}{\partial z}\right)$$

$$\frac{1}{\rho}\frac{\partial p}{\partial z} = -g$$

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0$$

Jednadžbe gibanja i kontinuiteta nakon integracije duž vertikale

$$g\frac{\partial \zeta}{\partial x} = \frac{f}{D}\mathbf{V} + \frac{1}{\rho}\left[\frac{\tau_x}{D} - \frac{\tau_{x,b}}{D}\right]$$

$$g\frac{\partial \zeta}{\partial y} = -\frac{f}{D}\mathbf{U} + \frac{1}{\rho}\left[\frac{\tau_y}{D} - \frac{\tau_{y,b}}{D}\right]$$

$$\frac{\partial \mathbf{U}}{\partial x} + \frac{\partial \mathbf{V}}{\partial y} = 0$$

Poprečnim deriviranjem dobiva se (uz f = const.):

$$f\left[\frac{\partial D}{\partial x}\frac{\partial \Psi}{\partial y}-\frac{\partial D}{\partial y}\frac{\partial \Psi}{\partial x}\right]=\frac{D}{\rho}\left[\frac{\partial \tau_y}{\partial x}-\frac{\partial \tau_x}{\partial y}\right]-\frac{1}{\rho}\left[\frac{\partial D}{\partial x}\tau_y-\frac{\partial D}{\partial y}\tau_x\right]-\frac{D}{\rho}\left[\frac{\partial \tau_{y,b}}{\partial x}-\frac{\partial \tau_{x,b}}{\partial y}\right]+\frac{1}{\rho}\left[\frac{\partial D}{\partial x}\tau_{y,b}-\frac{\partial D}{\partial y}\tau_{x,b}\right]$$

gdje je:

$$\tau_{x,b}=\rho r\frac{\mathbf{U}}{D}-n\tau_x$$
$$\tau_{y,b}=\rho r\frac{\mathbf{V}}{D}-n\tau_y$$

$$\mathbf{U}=-\frac{\partial \Psi}{\partial y}, \qquad \mathbf{V}=\frac{\partial \Psi}{\partial x},$$

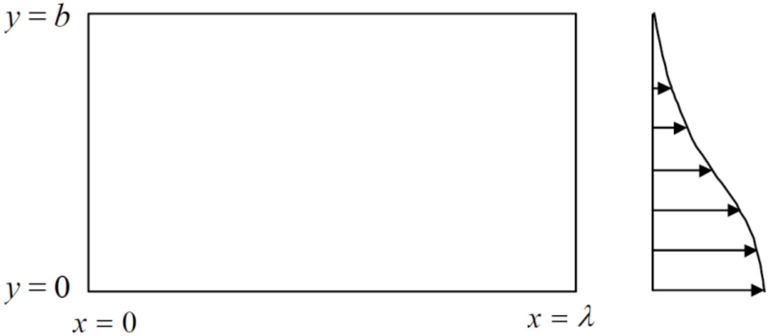
pa konačno rješavamo (uz $\Psi = 0$ duž obala):

$$f\left[\frac{\partial D}{\partial x}\frac{\partial \Psi}{\partial y}-\frac{\partial D}{\partial y}\frac{\partial \Psi}{\partial x}\right]+r\left[\frac{\partial^2 \Psi}{\partial x^2}+\frac{\partial^2 \Psi}{\partial y^2}\right]-\frac{2r}{D}\left[\frac{\partial D}{\partial x}\frac{\partial \Psi}{\partial x}+\frac{\partial D}{\partial y}\frac{\partial \Psi}{\partial y}\right]=\frac{D}{\rho}\left[\frac{\partial \tau_2}{\partial x}-\frac{\partial \tau_1}{\partial y}\right]-\frac{1}{\rho}\left[\frac{\partial D}{\partial x}\tau_2-\frac{\partial D}{\partial y}\tau_1\right]$$

$$\tau_1=\tau_x+n\tau_x\,,\;\; \tau_2=\tau_y+n\tau_y\,.$$

Prvi slučaj: ravno dno (*struje rotora vjetra*)

$$\frac{\partial^2 \Psi}{\partial x^2} + \frac{\partial^2 \Psi}{\partial y^2} = \alpha \sin \frac{\pi}{b} y$$

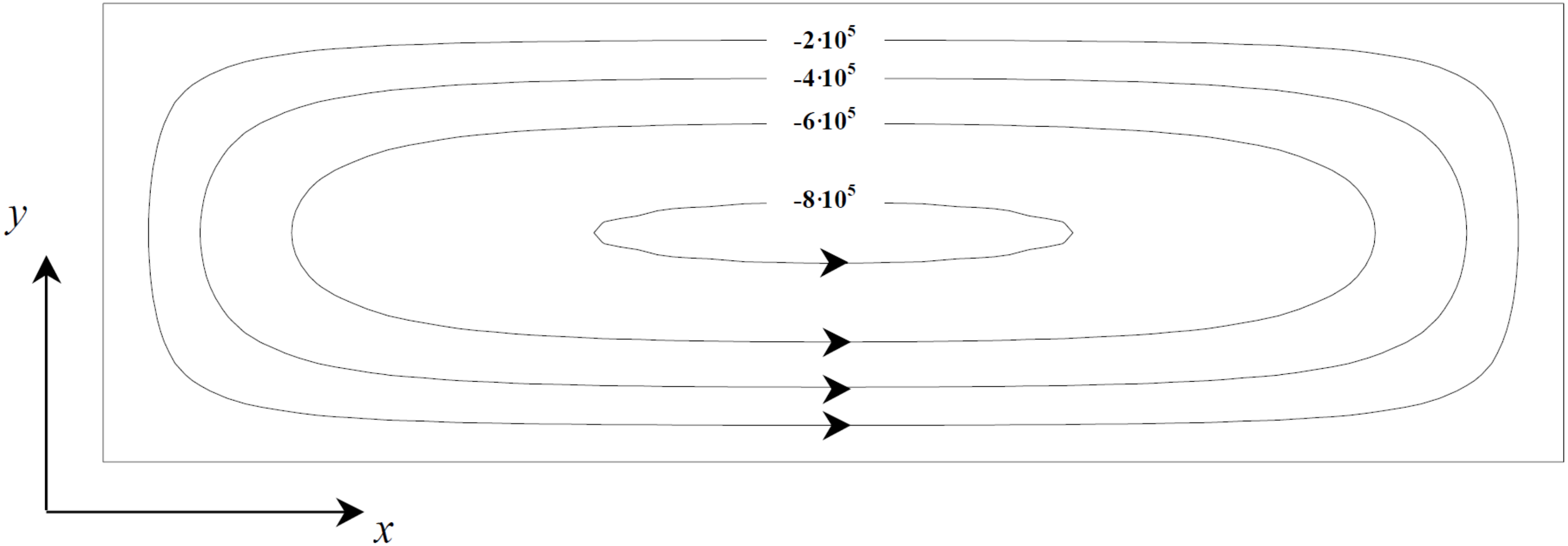


$$\tau_1 = F + F \cos \frac{\pi}{b} y$$

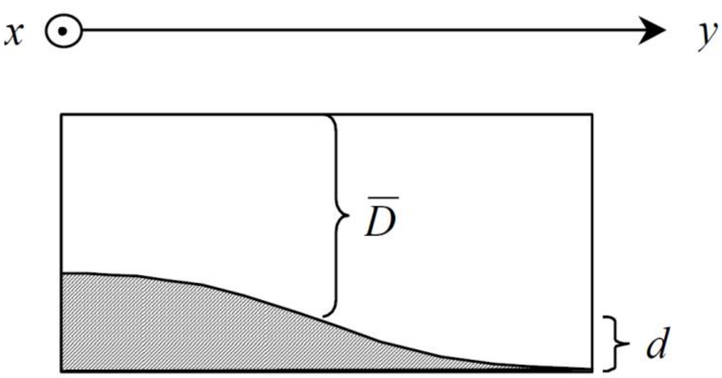
$$\alpha = \frac{D}{\rho r} \frac{F \pi}{b}$$

$$\Psi(x, y) = \alpha \frac{b^2}{\pi^2} \sin \frac{\pi}{b} y \left[e^{\frac{\pi}{b}(x-\lambda)} + e^{-\frac{\pi}{b}x} - 1 \right]$$

Struje rotora vjetra



Drugi slučaj: uniforman vjetar (*struje nagiba dna*)



$$\frac{\partial^2\Psi}{\partial x^2}+\frac{\partial^2\Psi}{\partial y^2}-\frac{f}{r}\frac{dD}{dy}\frac{\partial\Psi}{\partial x}-\frac{2}{D}\frac{dD}{dy}\frac{\partial\Psi}{\partial y}=\frac{1}{\rho r}\tau_1\frac{dD}{dy}$$

$$D=\overline{D}-d\cos\frac{\pi}{b}y$$

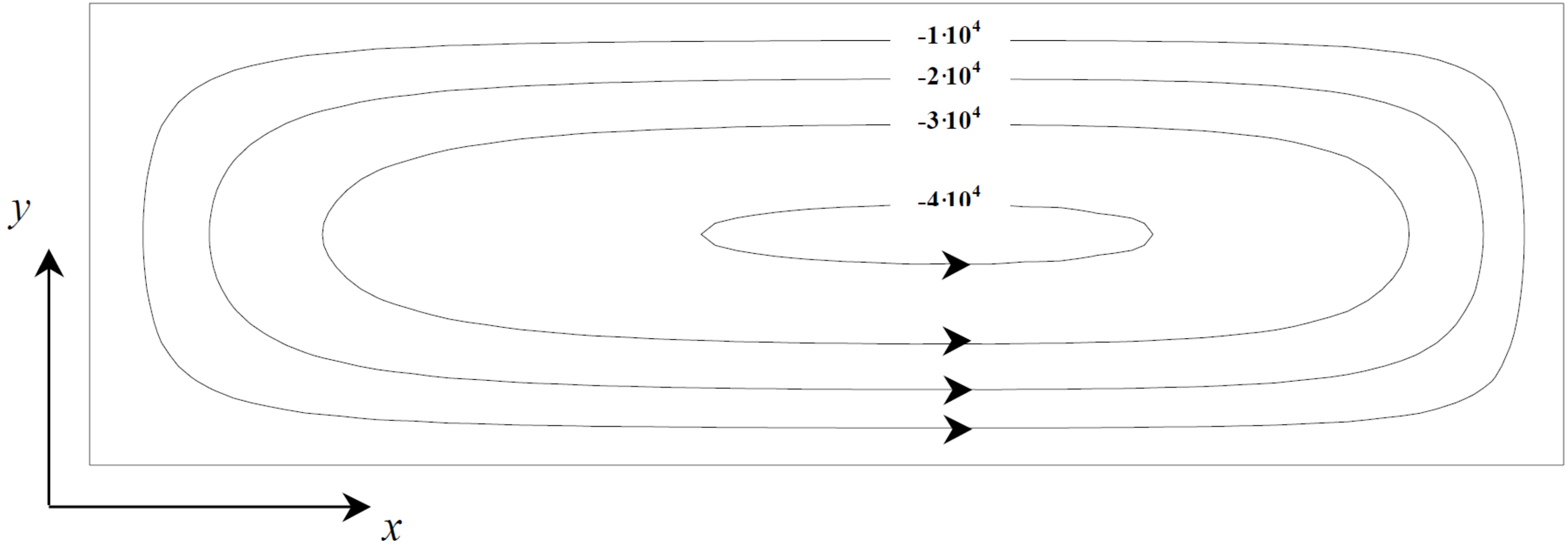
$$\frac{\partial^2\Psi}{\partial x^2}+\frac{\partial^2\Psi}{\partial y^2}+\alpha\frac{\partial\Psi}{\partial x}=\gamma\sin\frac{\pi}{b}y$$

$$\alpha=-\pi\frac{f}{r}\frac{d}{b},\quad \gamma=\frac{\tau_1 d\pi}{r\rho b}$$

$$\Psi(x,y)=\gamma\frac{b^2}{\pi^2}\sin\frac{\pi}{b}y\left[\frac{\left(1-e^{k_2\lambda}\right)e^{k_1x}+\left(e^{k_1\lambda}-1\right)e^{k_2x}}{e^{k_1\lambda}-e^{k_2\lambda}}-1\right],$$

$$k_1=-\frac{\alpha}{2}+\sqrt{\frac{\alpha^2}{4}+\frac{\pi^2}{b^2}},\quad k_1=-\frac{\alpha}{2}-\sqrt{\frac{\alpha^2}{4}+\frac{\pi^2}{b^2}}.$$

Struje nagiba dna



Treći slučaj: ravno dno i uniforman vjetar

$$\frac{\partial^2 \Psi}{\partial x^2} + \frac{\partial^2 \Psi}{\partial y^2} = 0$$

$$\Psi(0, y) = \Psi(\lambda, y) = \Psi(x, 0) = \Psi(x, b) = 0$$

$$\downarrow$$

$$\Psi = 0$$