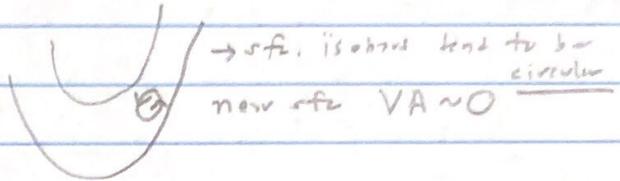
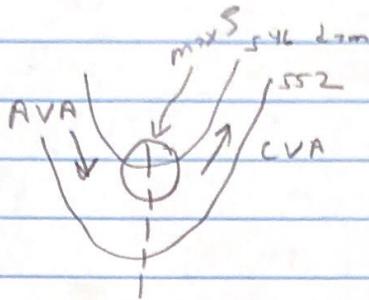


→  $w$  opposite in sign to forcing functions (11)  
 $w < 0 \Rightarrow w > 0$   
 $w > 0 \Rightarrow w < 0$

(1) VA

$-\frac{\partial(VA)}{\partial p}$  rate of change w/h " " of VA

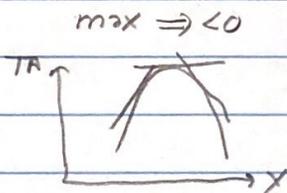


so  $-\frac{\partial(VA)}{\partial p} > 0 \Rightarrow w < 0$

(2) TA  $-\nabla_p^2(TA)$

TA sinusoidal  $\overline{TA} = 0$   $\left\{ \begin{array}{l} TA > 0 \text{ some places} \\ TA < 0 \text{ others} \end{array} \right.$

if  $-\nabla_p^2(TA) > 0 \Rightarrow w < 0$



so,  $TA > 0 \Rightarrow w < 0$   
(WA)

if  $-\nabla_p^2(TA) < 0 \Rightarrow w > 0$   
 min ⇒ > 0

⇒  $TA < 0 \Rightarrow w > 0$   
(CA)

(3) suppose  $S_y > 0$  in friction layer (where  $\frac{dS_y}{dp} = 0$ )

$$-\frac{d}{dp}(-KS_y)$$

as in Ekman layer

$$= -\frac{dK}{dp} S_y + K \frac{dS_y}{dp} \rightarrow 0$$

$$= -\left(-\frac{dK}{dp}\right) S_y$$

$< 0$

$K$  (effects of friction)

decreases w/ ht

if  $S_y > 0$

f.f.  $> 0 \Rightarrow w < 0$  Ekman pumping

if  $S_y < 0$

f.f.  $< 0 \Rightarrow w > 0$  Ekman suction

$$(4) -\nabla_p^2 \left( \frac{1}{C_p} \frac{d\theta}{dt} \right)$$

$$\frac{1}{C_p} \frac{d\theta}{dt} \text{ sinusoidal}$$

$$\overline{\frac{1}{C_p} \frac{d\theta}{dt}} = 0$$

heating in some places  
cooling in other

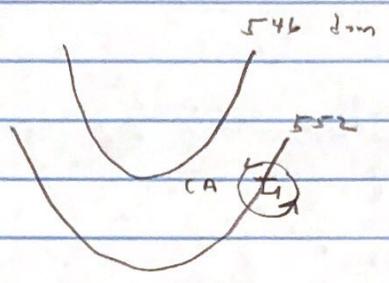
$$\frac{1}{C_p} \frac{d\theta}{dt} \text{ max} \Rightarrow \nabla^2(\ ) < 0 \Rightarrow \text{f.f.} > 0 \Rightarrow w < 0$$

$$\frac{1}{C_p} \frac{d\theta}{dt} \text{ min.} \Rightarrow \nabla^2(\ ) > 0 \Rightarrow \text{f.f.} < 0 \Rightarrow w > 0$$

"traditional" formulation of P.G. w-eqn

①  $\Phi(x, y, z)$  → TA & VA fields

② TA & VA forcing fns. in w-eqn often opposite to each other  
not independent



③ VA forcing function — need to know  $\Phi$  at several levels

④ forcing functions not Galilean invariant  
→ depend upon reference frame  
fundamental physical processes should be independent of reference frame

Go to T to Trenberth notes