


“Avaliação do impacto dos eddies transientes no fluxo zonal durante um episódio de bloqueio usando o fluxo diagnóstico localizado de Eliassen-Palm”

# AN ASSESSMENT OF THE IMPACT OF TRANSIENT EDDIES ON THE ZONAL FLOW DURING A BLOCKING EPISODE USING LOCALIZED ELIASSEN-PALM FLUX DIAGNOSTICS

Trenberth, K.E., 1986: *An Assessment of the Impact of Transient Eddies on the Zonal Flow during a Blocking Episode Using Localized Eliassen-Palm Flux Diagnostics*. J. Atmos. Sci., 43, 2070–2087

# INTRODUÇÃO

- ▶ Trenberth (1986): descrição de dois eventos de bloqueio no HS no inverno de 1979
- ▶ Altas de bloqueios: tendência de se reformular, intensificar numa mesma localização
- ▶ Assinatura característica na circulação geral
- ▶ Neste artigo: examinar o episódio de bloqueio com ênfase no papel e influência dos eddies transientes no fluxo zonal médio
  - ▶ Eddies ajudam a manter ou destruir o bloqueio?

- ▶ No bloqueio estudado:
    - ▶ Existia localmente uma forte estrutura de partição do jato
    - ▶ Forte cisalhamento meridional
  - ▶ Efeitos baroclínicos
  - ▶ Desenvolver teoria mais abrangente
- 

# FLUXO LOCALIZADO ELIASSEN-PALM (E-P)

- ▶ O fluxo local E-P está relacionado com o *E-vector* de Hoskins et. al (1983) e Plumb (1985,1986)
- ▶ A divergência deste fluxo dá a principal forçante localizada do fluxo zonal médio pelos eddies transientes
- ▶ Principal vantagem de usar o fluxo E-P e sua divergência:
  - ▶ O termo proporcional a divergência deste fluxo será o único termo descrevendo a forçante dos eddies no fluxo médio, que aparece nas equações do momento e da termodinâmica quando transformadas
- ▶ Transformação das equações: alterá-las de tal forma que as mudanças internas que são consequências de se manter o equilíbrio hidrostático e quase-geostrófico estejam em um único termo

# A. PLANO-F QUASE-GEOSTRÓFICO

$$z = \ln(p_0/p)$$

$$\frac{du}{dt} - fv + \frac{\partial \Phi}{\partial x} = \mathcal{F}_x$$

$$\frac{dv}{dt} + fu + \frac{\partial \Phi}{\partial y} = \mathcal{F}_y$$

$$\frac{d}{dt} \Phi_z + wS = \kappa Q$$

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{1}{\rho_0} \frac{\partial}{\partial z} \rho_0 w = 0$$

$$\Phi_z = RT$$

$$\frac{d}{dt} = \frac{\partial}{\partial t} + u \frac{\partial}{\partial x} + v \frac{\partial}{\partial y}$$

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TRANSFORMAÇÃO



$$D\bar{u} - f\bar{v}^* = \nabla \cdot \bar{\mathbf{E}}_u + \bar{\mathcal{F}}_x$$

$$D\bar{v} + f\bar{u}^* = \nabla \cdot \bar{\mathbf{E}}_v + \bar{\mathcal{F}}_y$$

$$D\bar{\Phi}_z + w^*S = \kappa \bar{Q}$$

$$\bar{\mathbf{E}}_u = \left[ \frac{1}{2}(\bar{v}'^2 - \bar{u}'^2), -\bar{u}'\bar{v}', f \frac{\bar{v}'\bar{\Phi}'_z}{S} \right]$$

$$\bar{\mathbf{E}}_v = \left[ -\bar{u}'\bar{v}', -\frac{1}{2}(\bar{v}'^2 - \bar{u}'^2), -f \frac{\bar{u}'\bar{\Phi}'_z}{S} \right]$$

$$\nabla = \left[ \frac{\partial}{\partial x}, \frac{\partial}{\partial y}, \frac{1}{\rho_0} \frac{\partial}{\partial z} \rho_0 \right]$$

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$$\mathbf{E} = \begin{bmatrix} \frac{1}{2}(\bar{v}'^2 - \bar{u}'^2) & -\bar{u}'\bar{v}' & f \frac{\bar{v}'\bar{\Phi}'_z}{S} \\ -\bar{u}'\bar{v}' & -\frac{1}{2}(\bar{v}'^2 - \bar{u}'^2) & -f \frac{\bar{u}'\bar{\Phi}'_z}{S} \\ 0 & 0 & 0 \end{bmatrix}$$

Vetor E

Forçantes restantes dos eddies estão na divergência deste vetor



## B. GEOMETRIA ESFÉRICA

$$\nabla = \left[ \frac{\partial}{\partial x'}, \frac{1}{\cos\phi} \frac{\partial}{\partial y'} \cos\phi, \frac{1}{\rho_0} \frac{\partial}{\partial z'} \rho_0 \right].$$

$$\mathbf{E}_u = \left[ \frac{1}{2} (\overline{v'^2} - \overline{u'^2}), -\overline{u'v'}, f \frac{\overline{v'\Phi'_z}}{S} \right] \cos\phi$$

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Foco:  $\text{div } \mathbf{E}_u$

# O EPISÓDIO DE BLOQUEIO

- ▶ 20 de julho a 31 de agosto de 1979 (43 dias – Trenberth, 1986)
  - ▶ Centrado em 50°S, 160°W
- 

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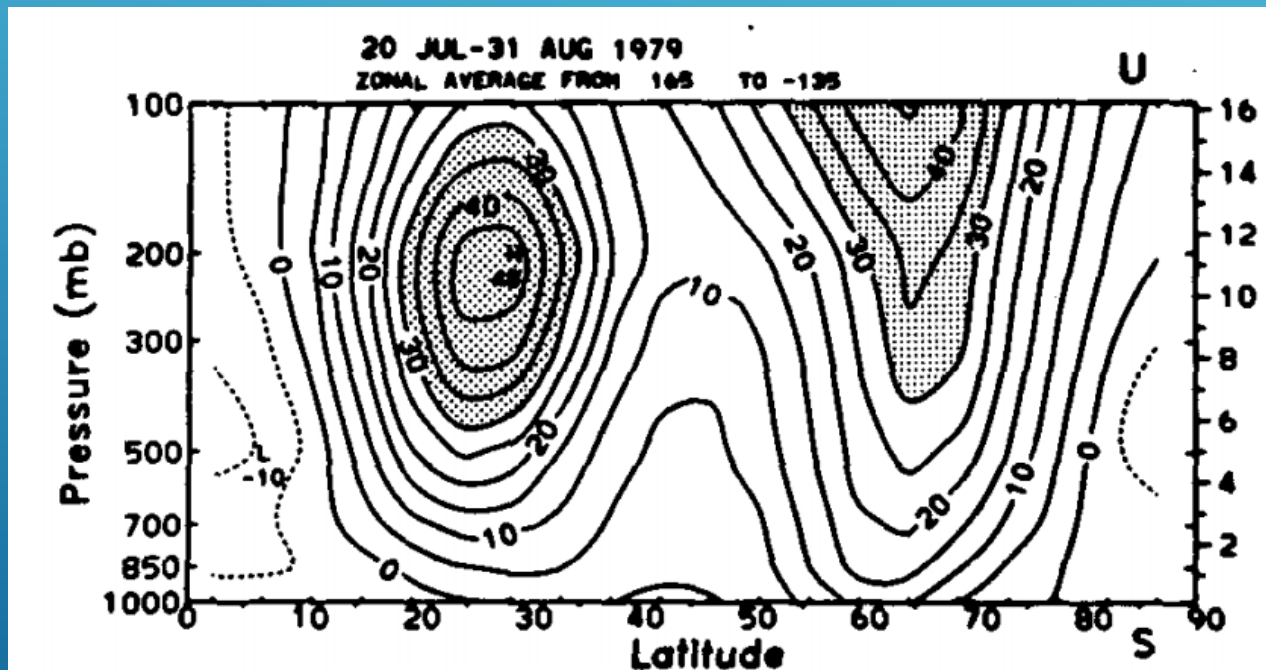


FIG. 1. Cross section of westerly wind component averaged over 165°E–135°W for 20 July–31 August 1979 in  $\text{m s}^{-1}$ . Winds greater than  $30 \text{ m s}^{-1}$  are stippled.

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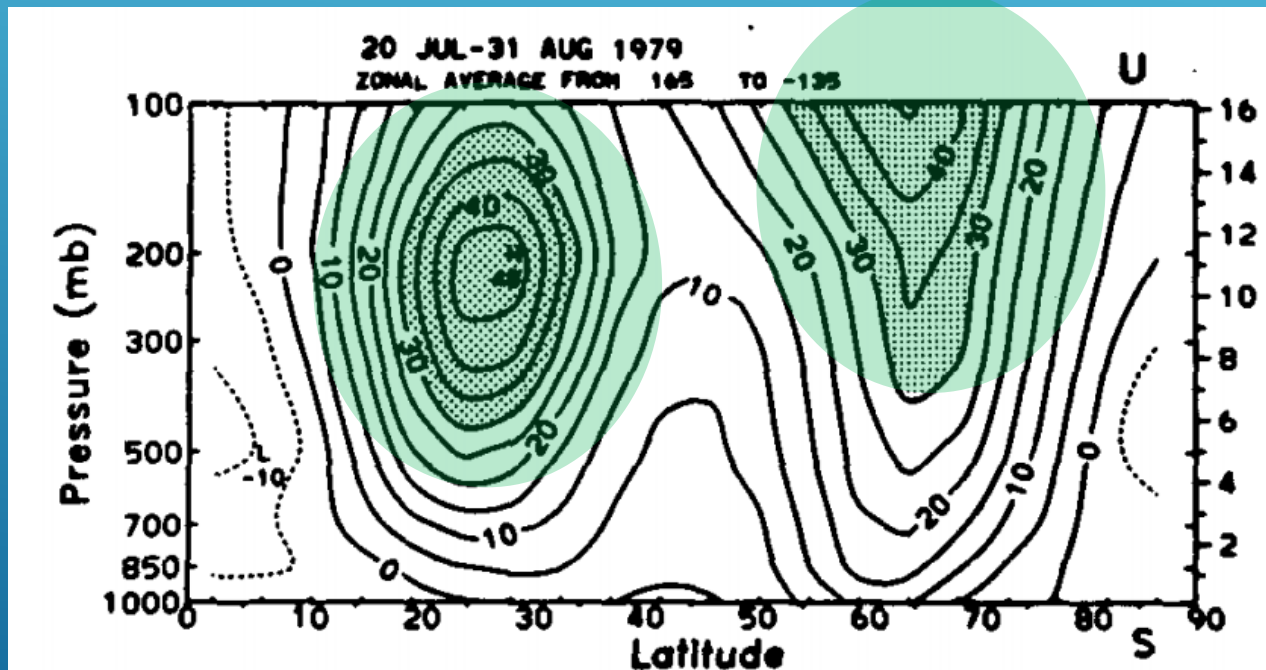


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Estrutura dupla de jato

# O EPISÓDIO DE BLOQUEIO

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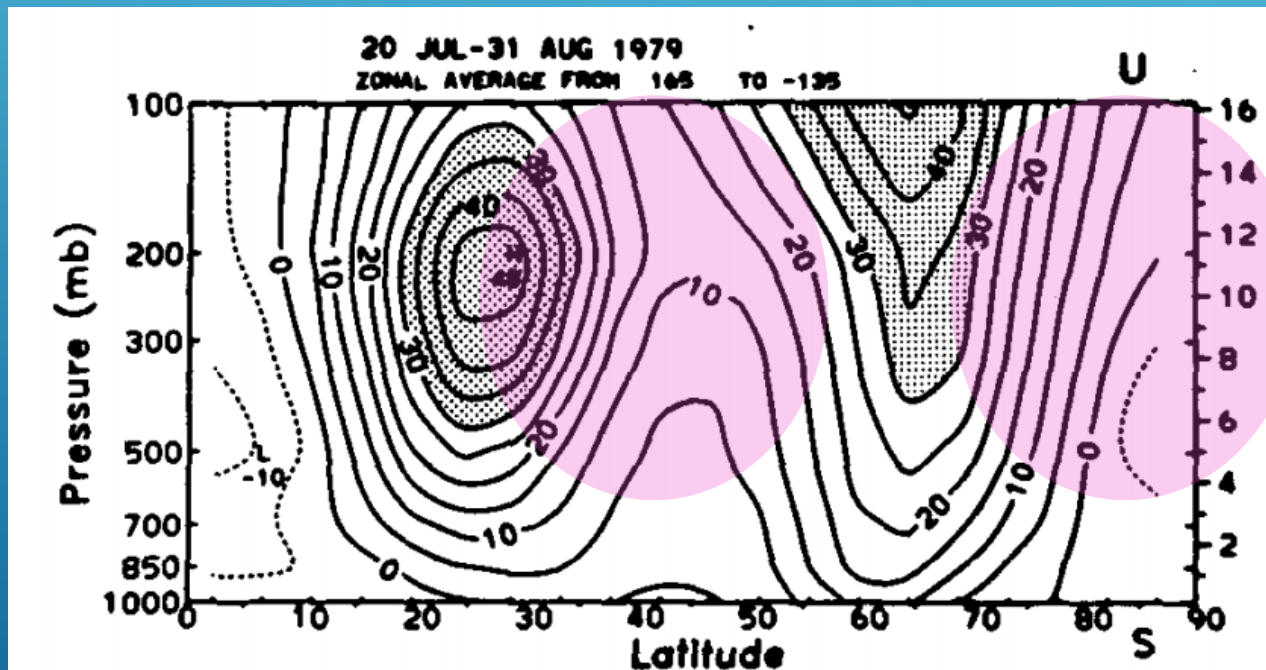


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Forte cisalhamento no flanco direcionado ao polo



# A. INST. BAROTRÓPICA

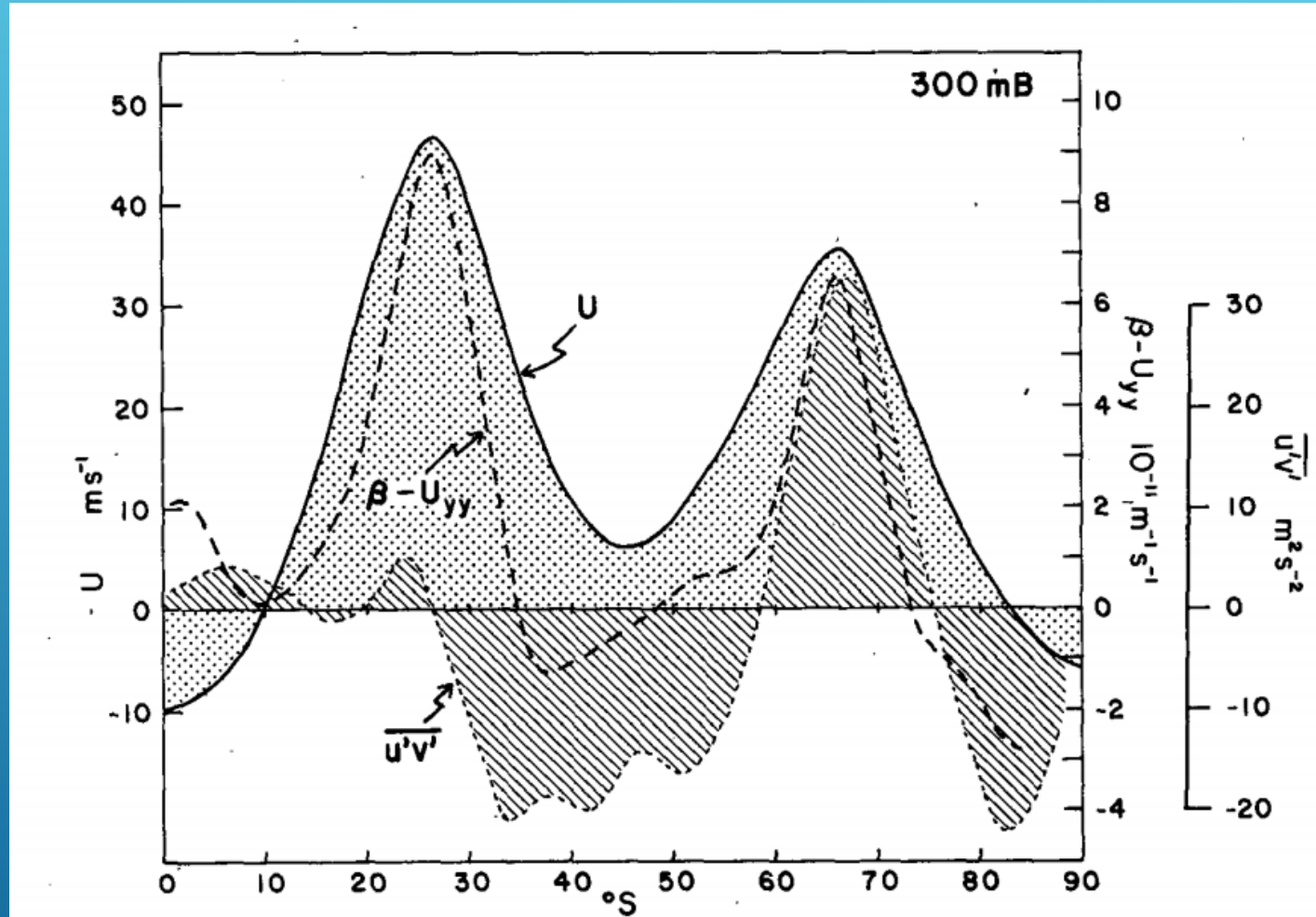


FIG. 2. Profiles at 300 mb over 165°E-135°W for 20 July-31 August 1979. (i) Westerly wind  $u$ , scale at left is in  $\text{m s}^{-1}$ ; (ii)  $\beta - u_{yy}$  computed in spherical geometry (see text), dashed, scale at right in  $10^{-11} \text{ m}^{-1} \text{ s}^{-1}$ ; (iii)  $u'v'$  dotted, scale at far right, in  $\text{m}^2 \text{ s}^{-2}$ .

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$$\frac{2\Omega \cos\phi}{a} - \frac{1}{a} \frac{\partial}{\partial\phi} \left[ \frac{1}{a \cos\phi} \frac{\partial}{\partial\phi} (u \cos\phi) \right]$$

=0 para existir inst. barotrópica

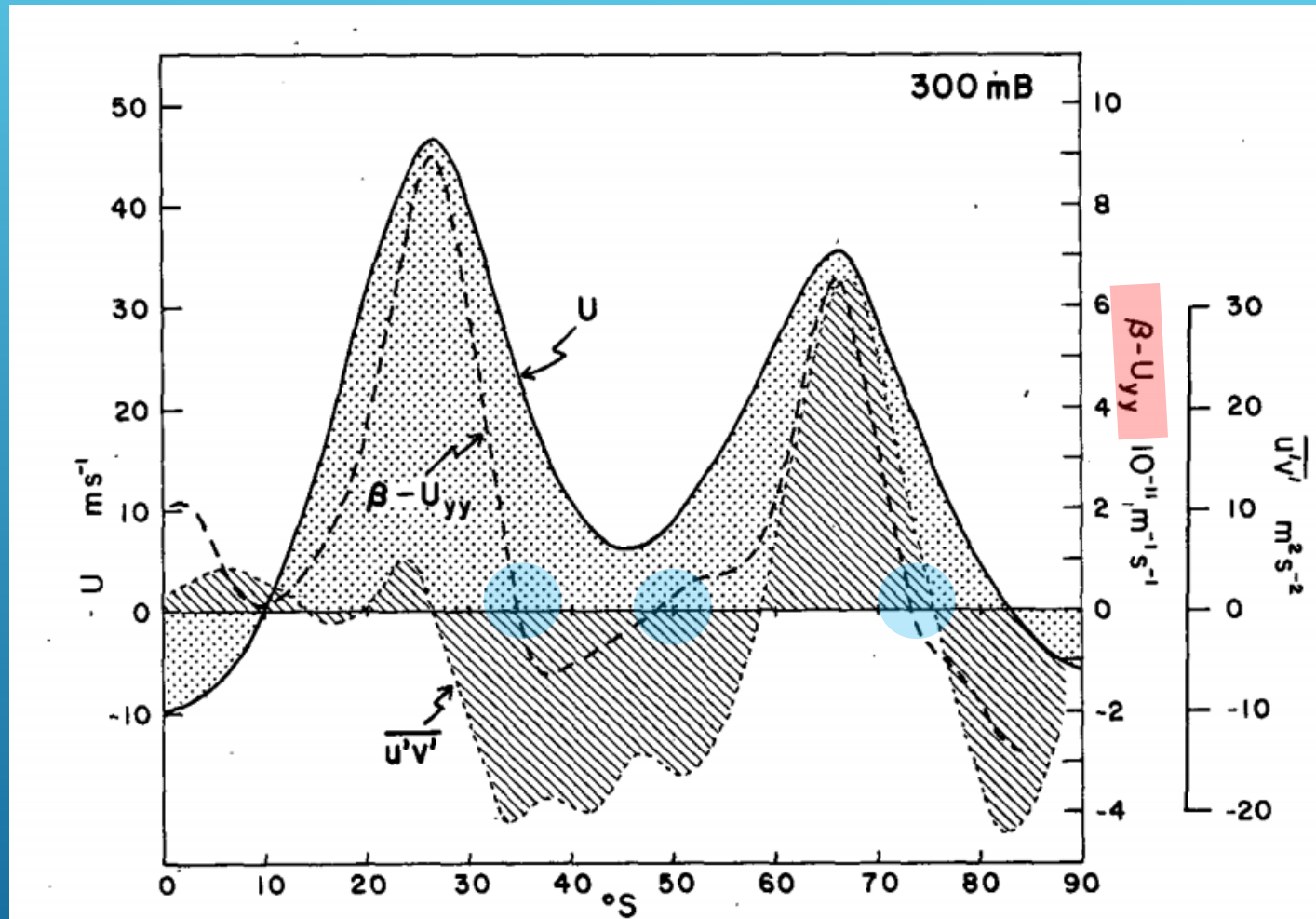


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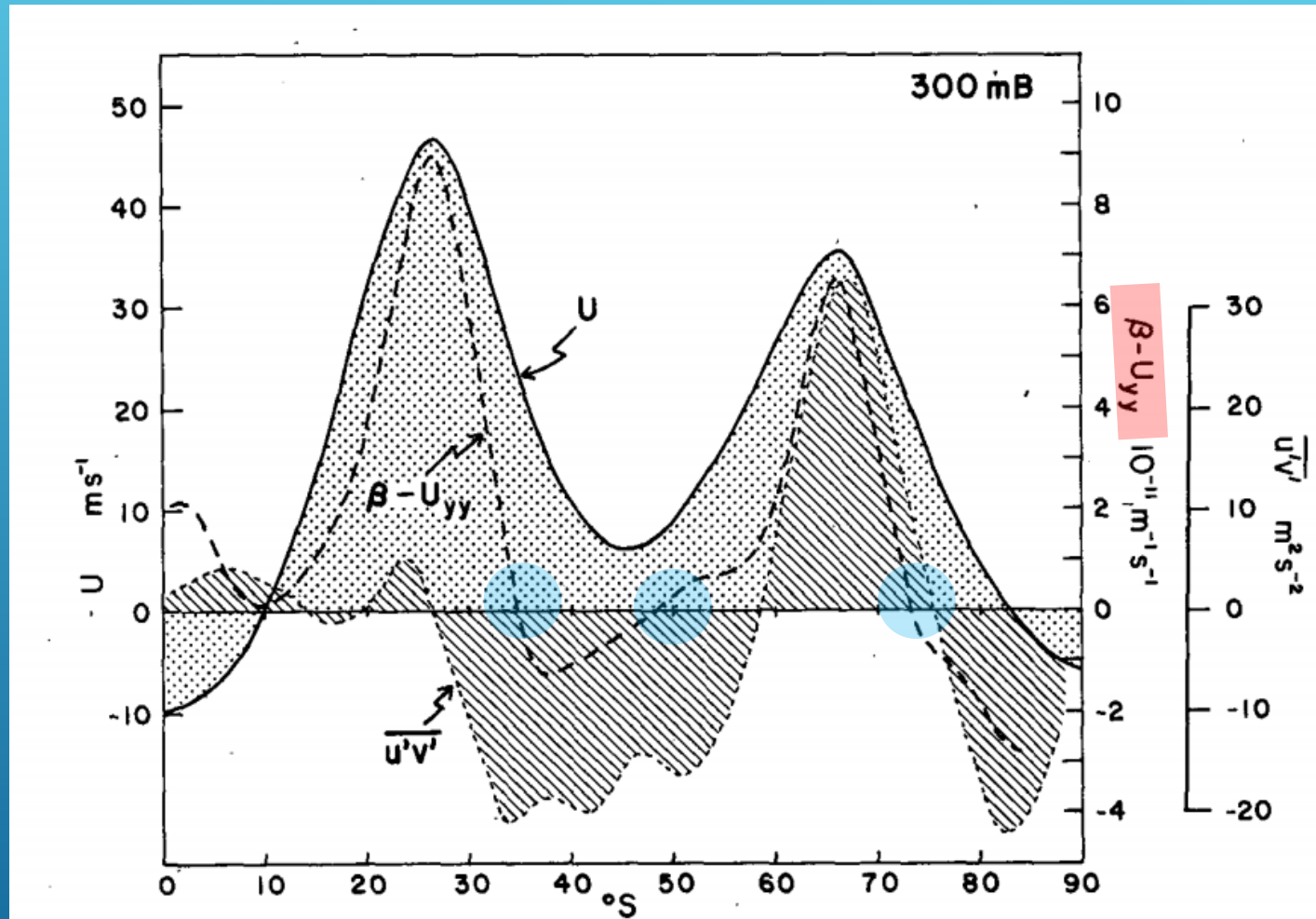


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Eddies crescendo barotropicamente no flanco dos jatos direcionado ao polo

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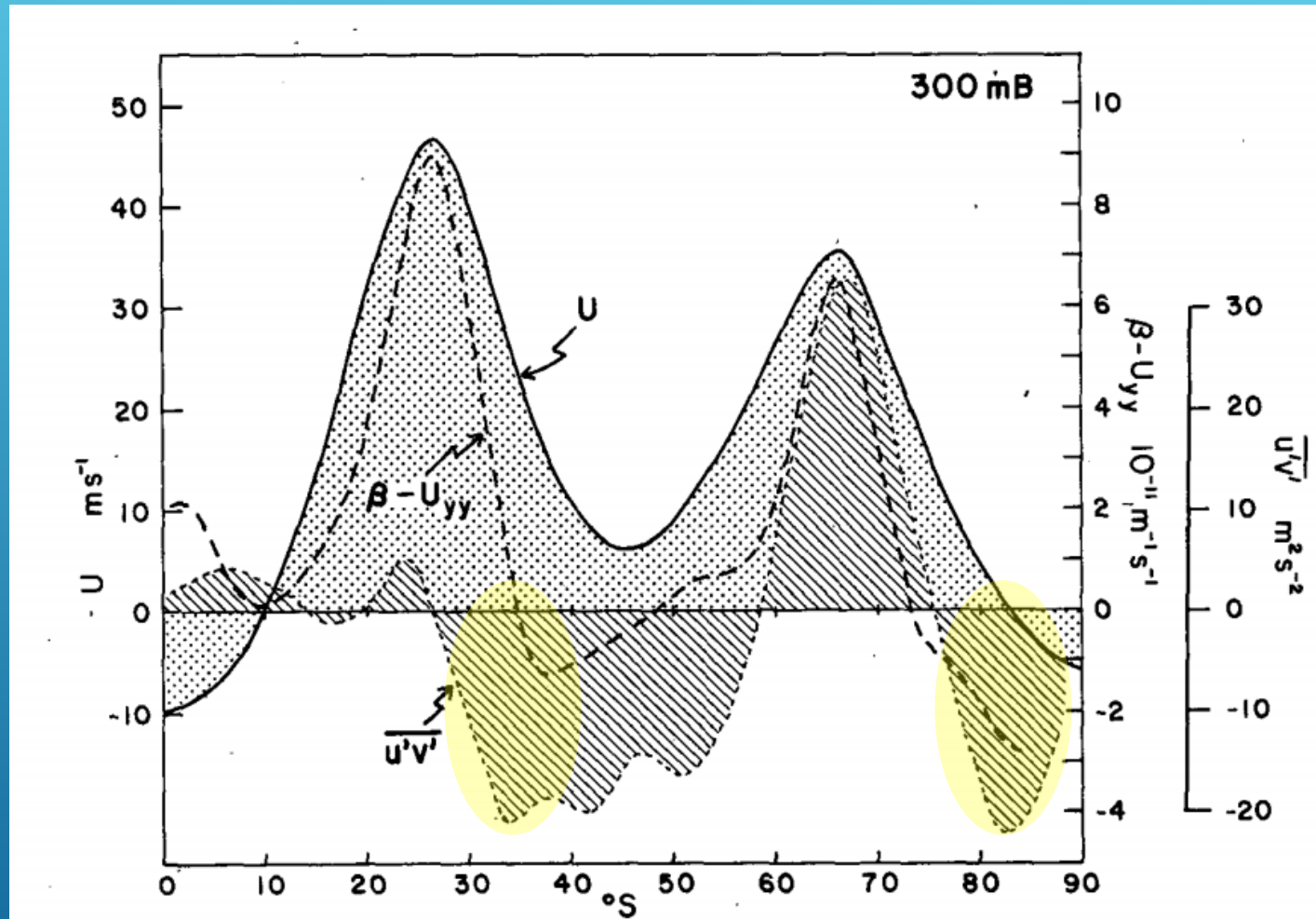


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Divergência de momento de oeste para fora dos jatos

- ▶ Filtragem para remover os n.º de onda 1-4 (responsáveis pela estrutura dos jatos)



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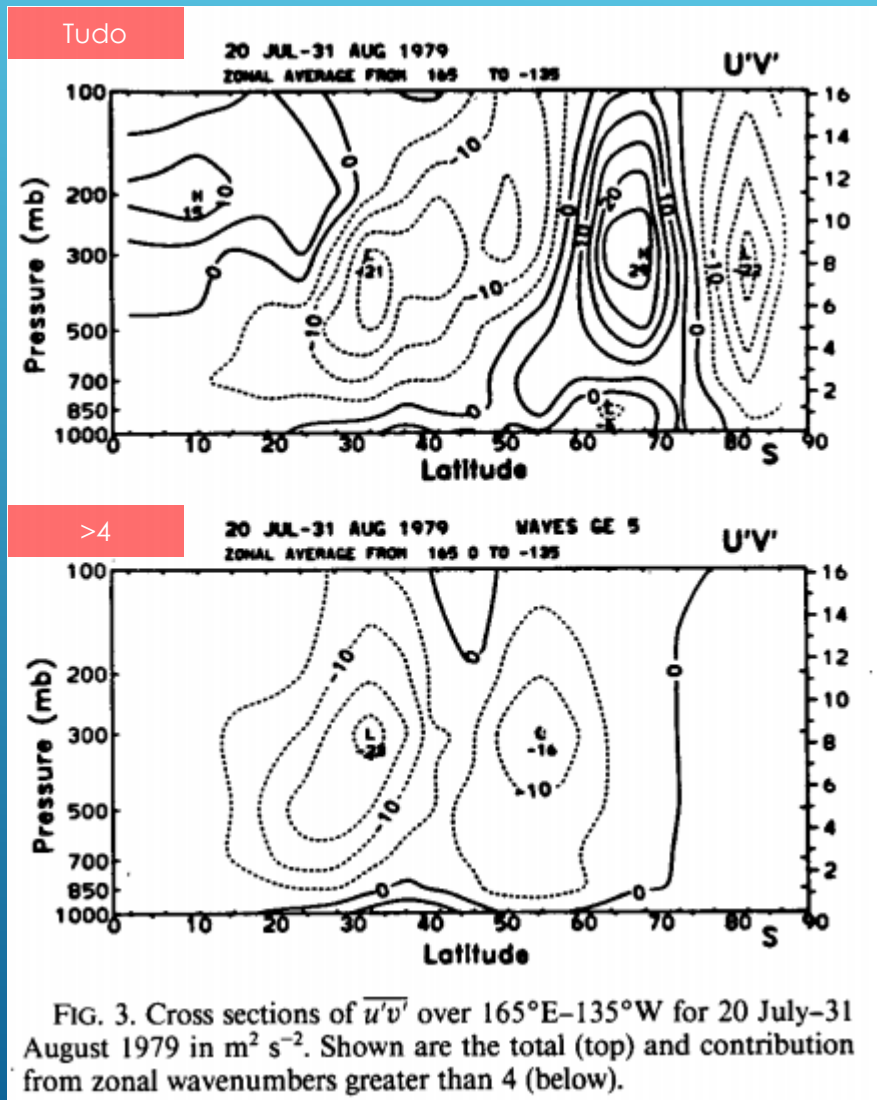
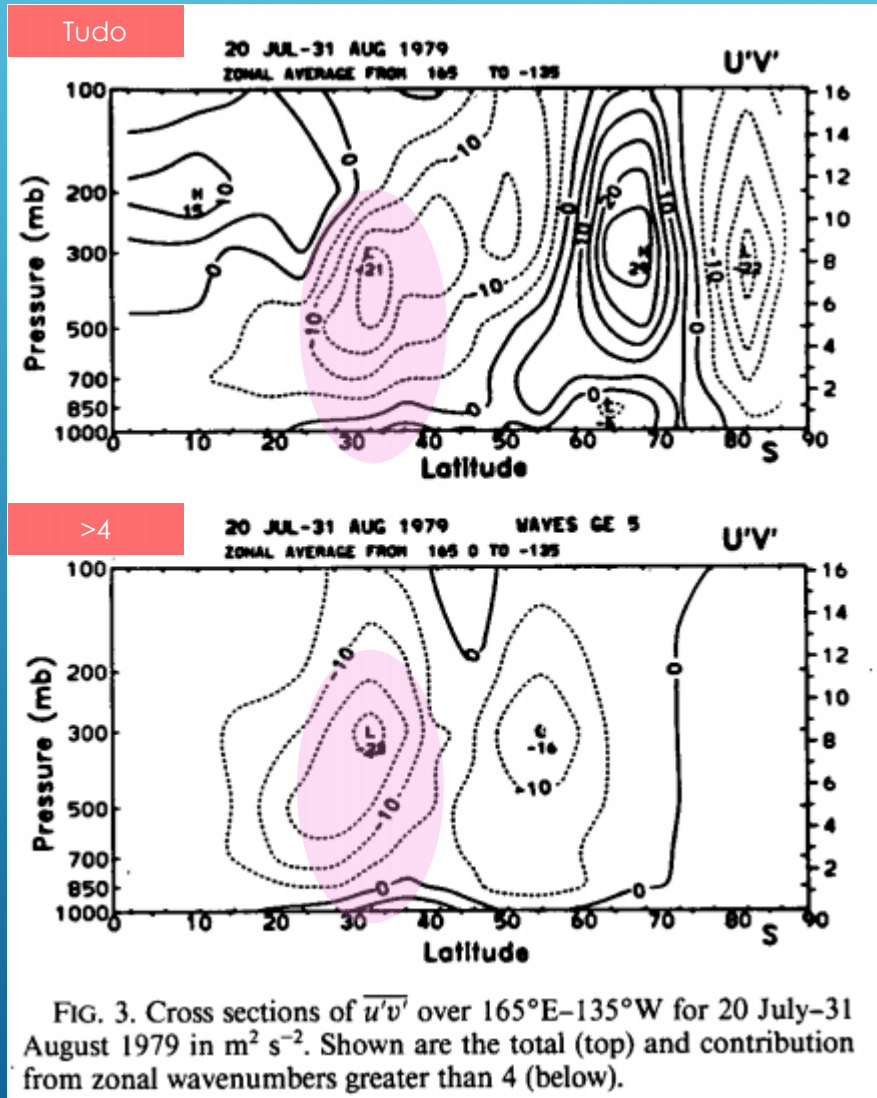


FIG. 3. Cross sections of  $\overline{u'v'}$  over  $165^{\circ}\text{E}-135^{\circ}\text{W}$  for 20 July-31 August 1979 in  $\text{m}^2 \text{s}^{-2}$ . Shown are the total (top) and contribution from zonal wavenumbers greater than 4 (below).

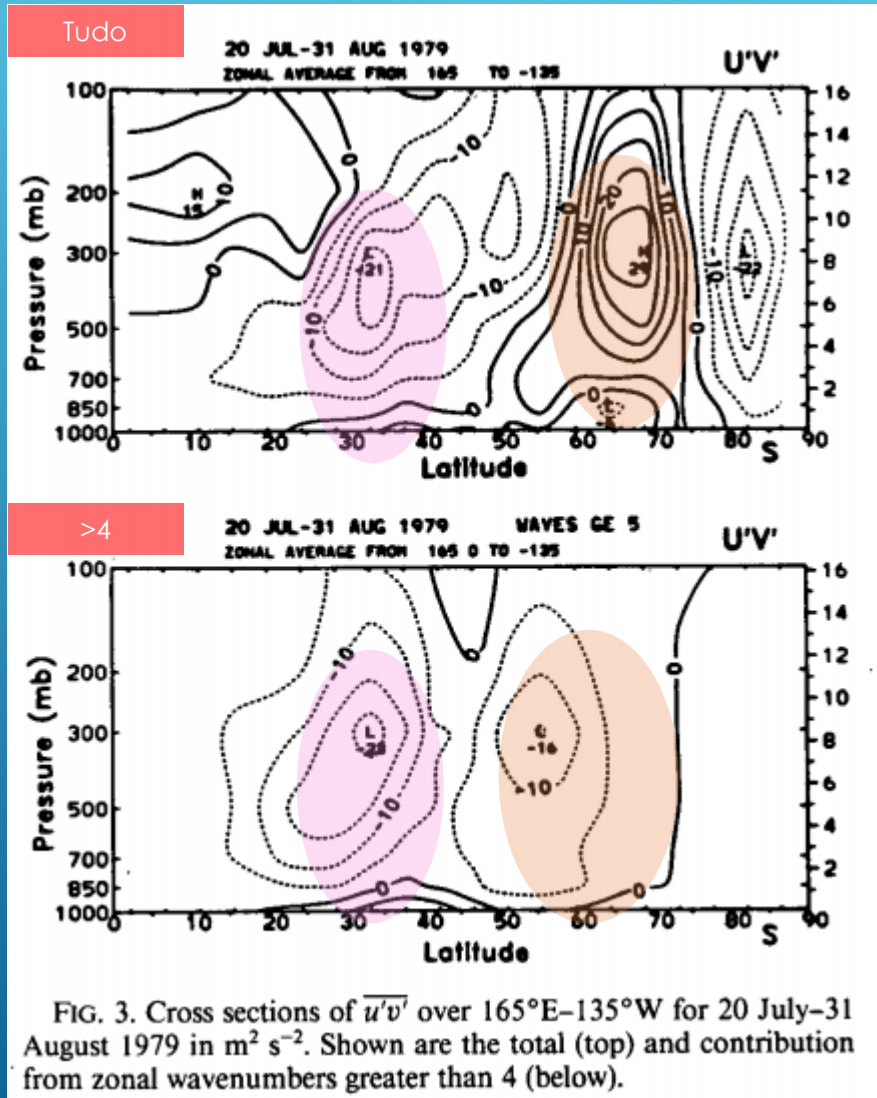
- ▶ Filtragem para remover os n.º de onda 1-4 (responsáveis pela estrutura dos jatos)



Fluxo de momento permanece nas lat. menores



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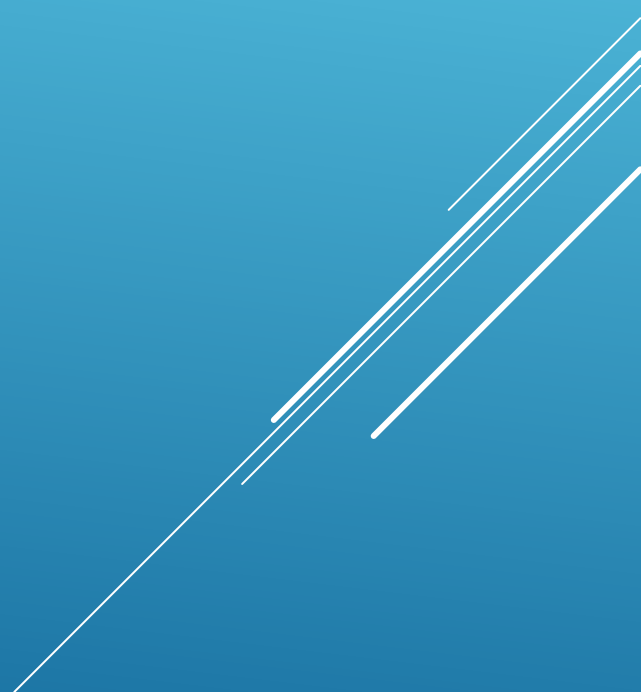
Fluxo de momento permanece nas lat. menores

Fluxo nas ondas maiores (<4)

Permanece o forte fluxo de momento de oeste saindo do jato subtropical pelos eddies transientes de menor escala, que contribuem para o crescimento dos eddies através de processos barotrópicos (apenas no flanco polar do jato sub)

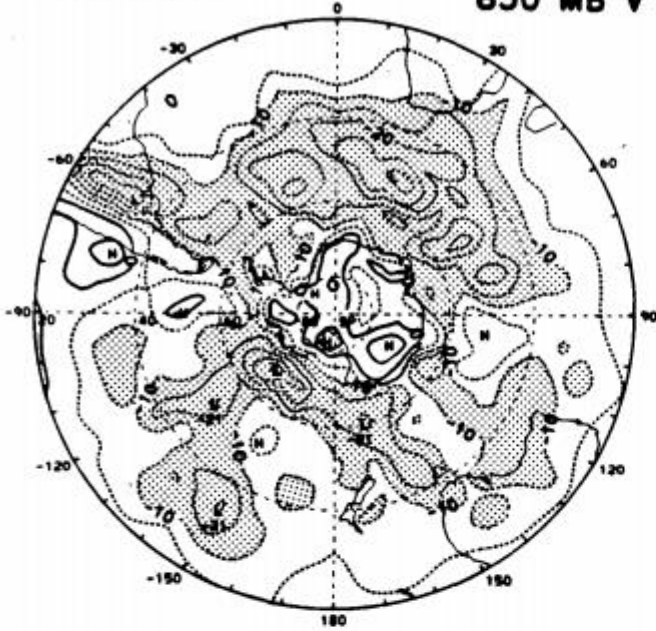
# B. OUTRAS ESTATÍSTICAS

- ▶ Jatos  $\Leftrightarrow$  fortes gradientes de temperatura  $\Leftrightarrow$  processos baroclínicos



20 JUL-31 AUG 1979

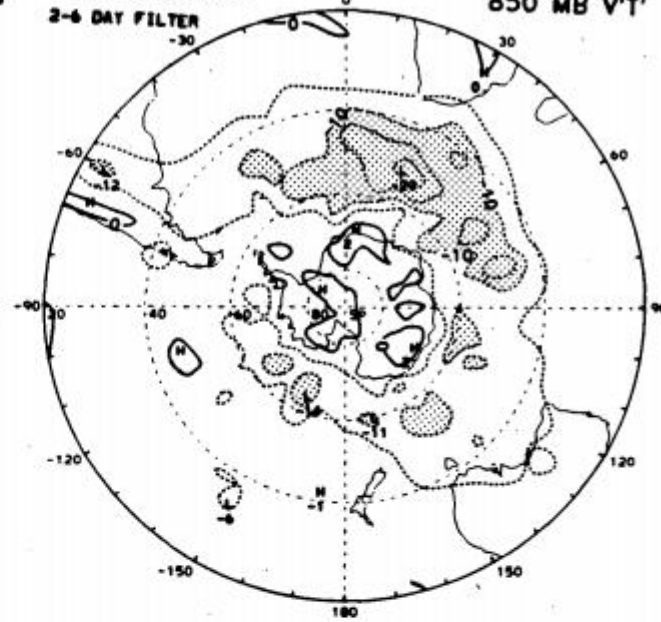
850 MB  $\overline{v'T}$



20 JUL-31 AUG 1979

2-6 DAY FILTER

850 MB  $\overline{v'T}$



20 JUL-31 AUG 1979

WAVES GE 5

850 MB  $\overline{v'T}$

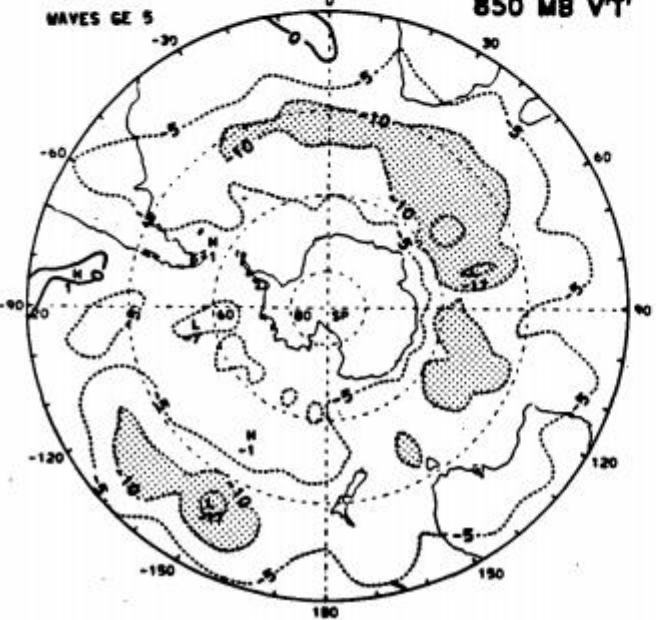


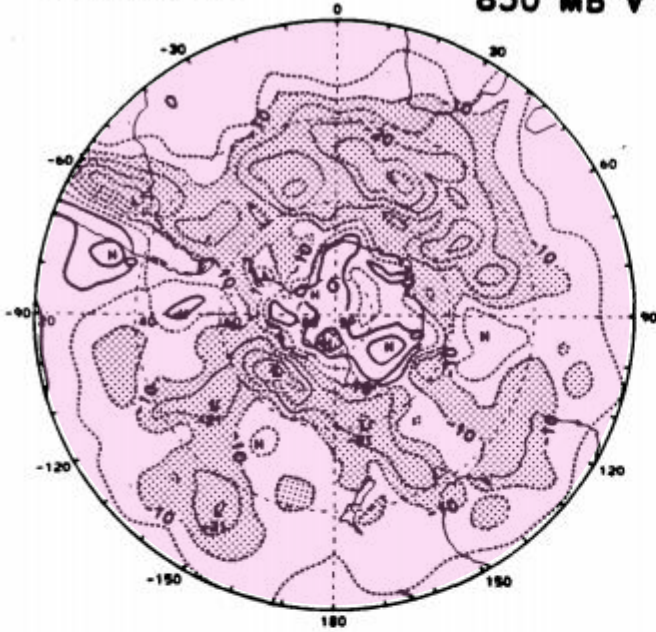
FIG. 5. Transient northward heat flux  $\overline{v'T}$  at 850 mb for 20 July-31 August 1979. Values less than  $-10^{\circ} \text{ m s}^{-1}$  are stippled. Shown are the total (top left), and contributions from 2-6 day period waves (top right) and wavenumbers greater than 4 (lower left).

Flujo de calor (transientes)



20 JUL-31 AUG 1979

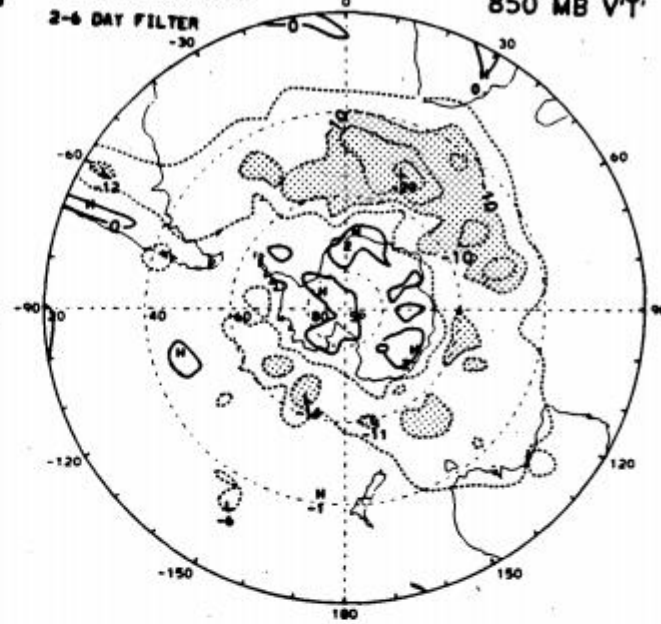
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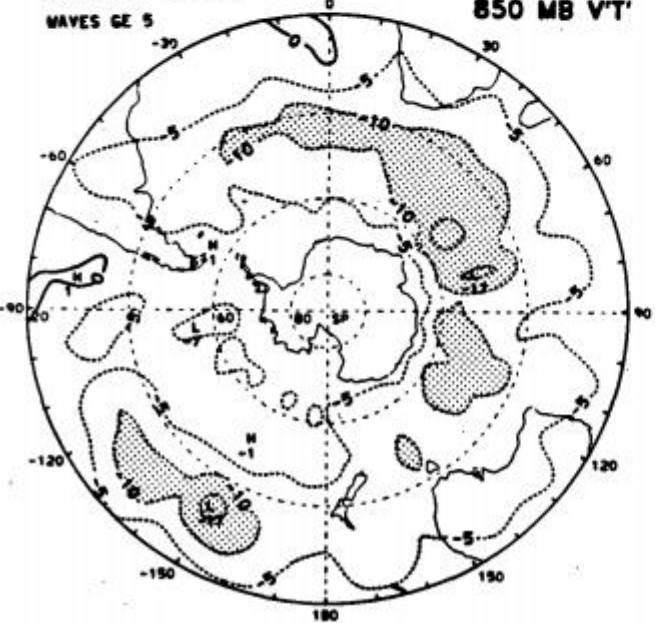
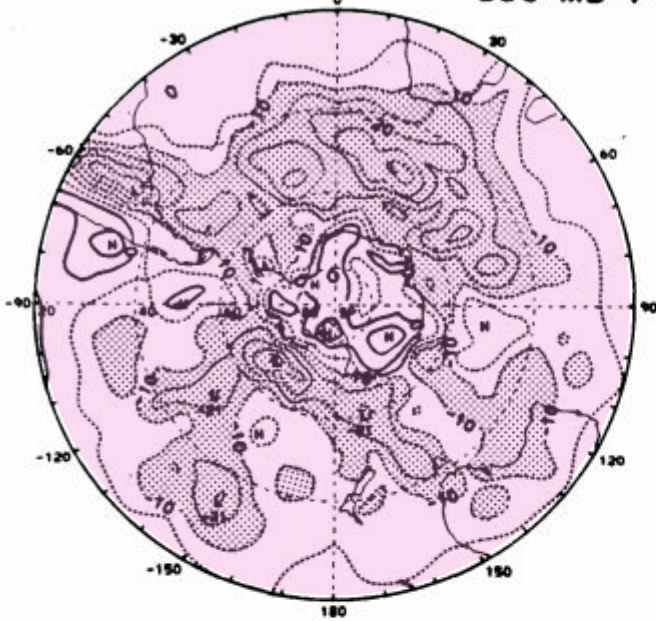


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Todas ondas

20 JUL-31 AUG 1979

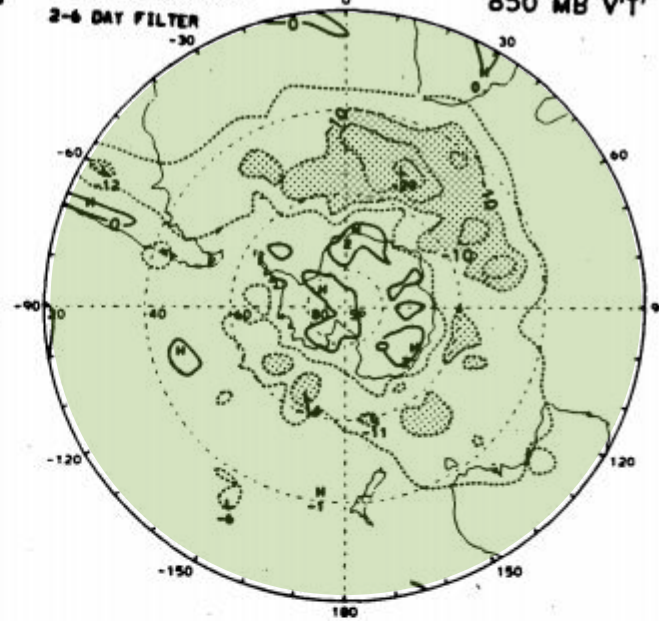
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2-6 DAY FILTER

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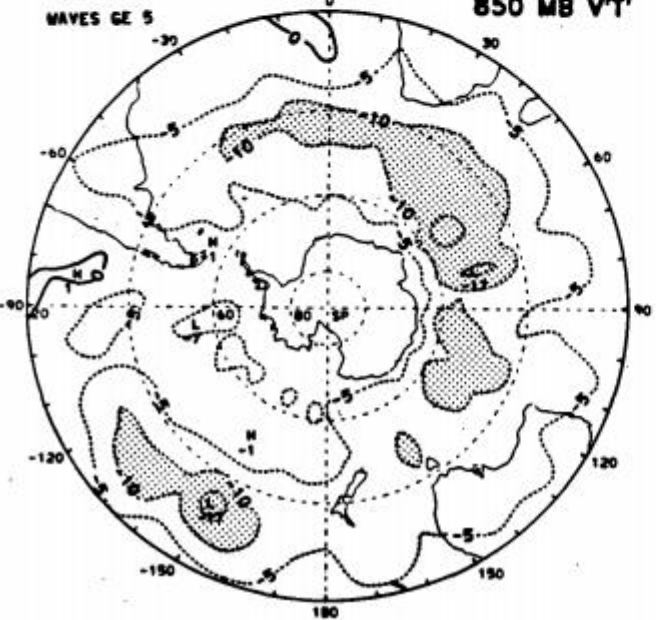


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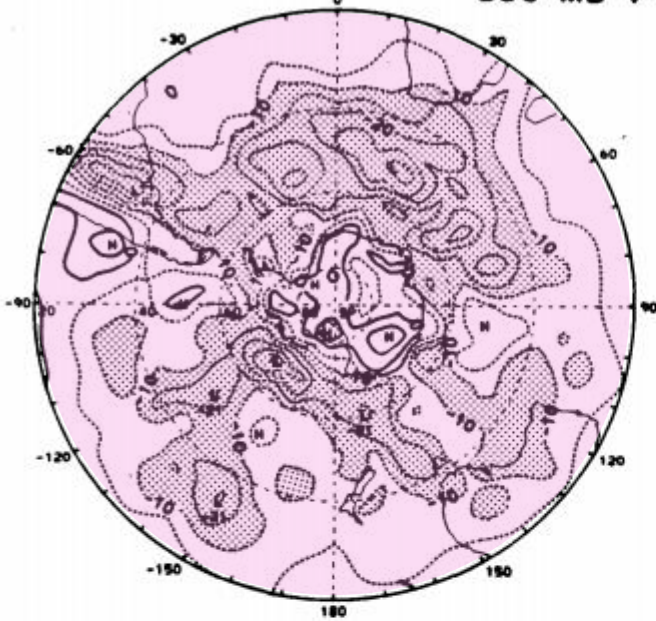
Todas ondas

Ondas com períodos de 2 a 6 dias



20 JUL-31 AUG 1979

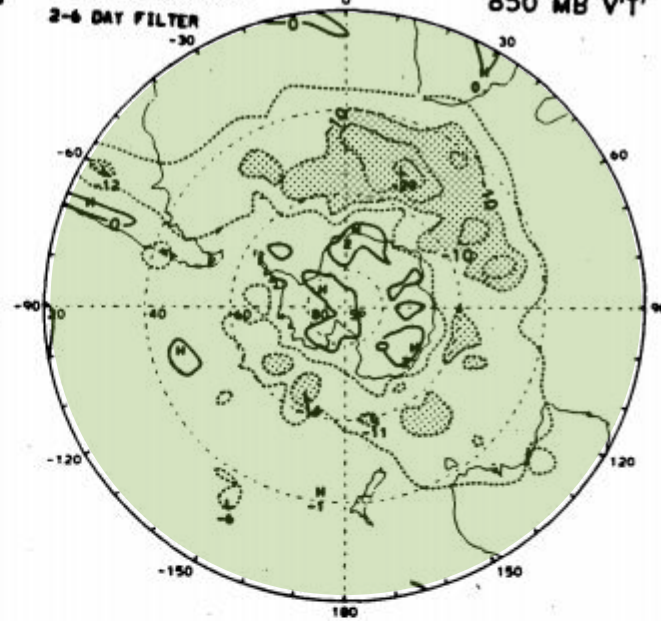
850 MB  $\overline{v'T'}$



20 JUL-31 AUG 1979

2-6 DAY FILTER

850 MB  $\overline{v'T'}$



20 JUL-31 AUG 1979

WAVES GE 5

850 MB  $\overline{v'T'}$

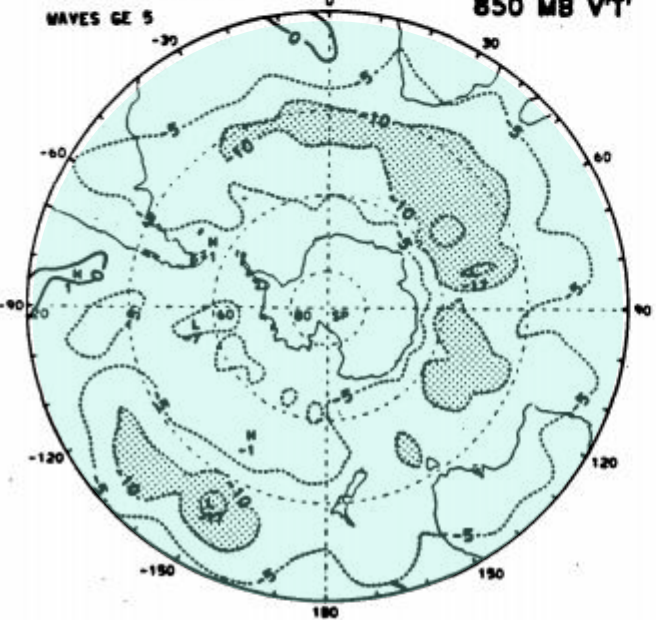


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Todas ondas

Ondas com períodos de 2 a 6 dias

Nº de onda >4

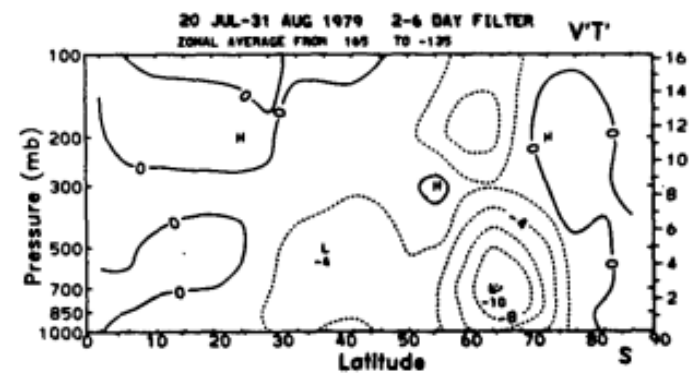
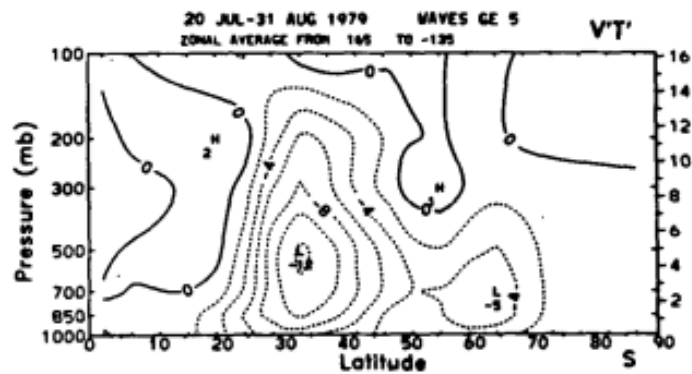
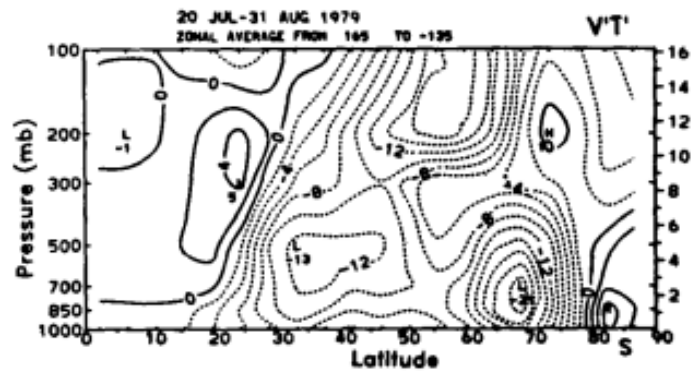


FIG. 6.  $\overline{v'T'}$  over  $165^{\circ}\text{E}-135^{\circ}\text{W}$  for 20 July-31 August 1979 in  $\text{K m s}^{-1}$ . Shown are the total (top), and contributions from wavenumbers greater than 4 (middle) and 2-6 day period waves (bottom).

Fluxo de calor (transientes): seção vertical (média entre  $165^{\circ}\text{E} - 135^{\circ}\text{W}$ )

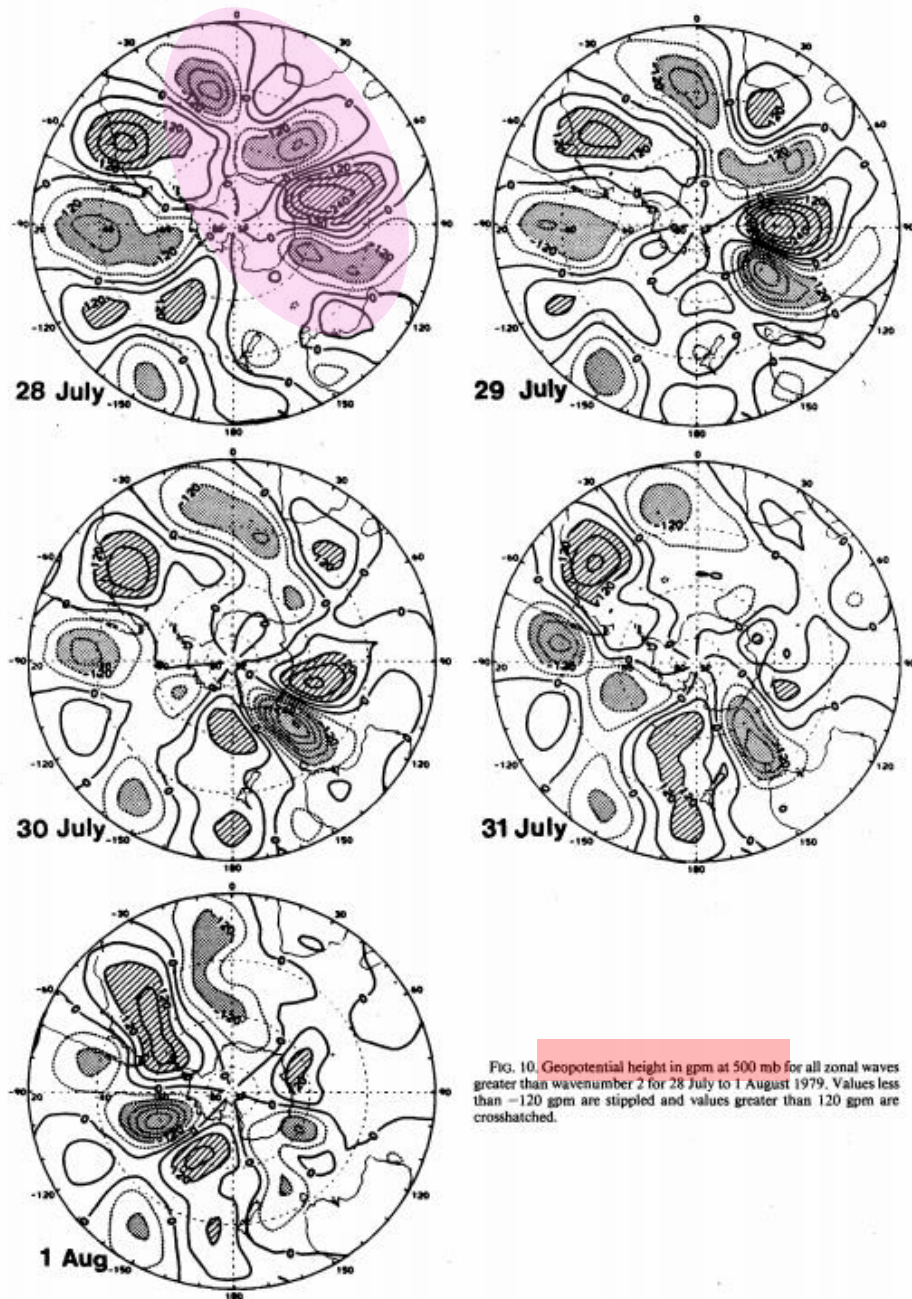
Eddies transientes “bloqueados” de entrar nas regiões de alta do bloqueio

Atividade ondulatória direcionada para norte ou sul seguindo a partição do jato

Em latitudes maiores os n° de onda 3 e 4 são mais importantes

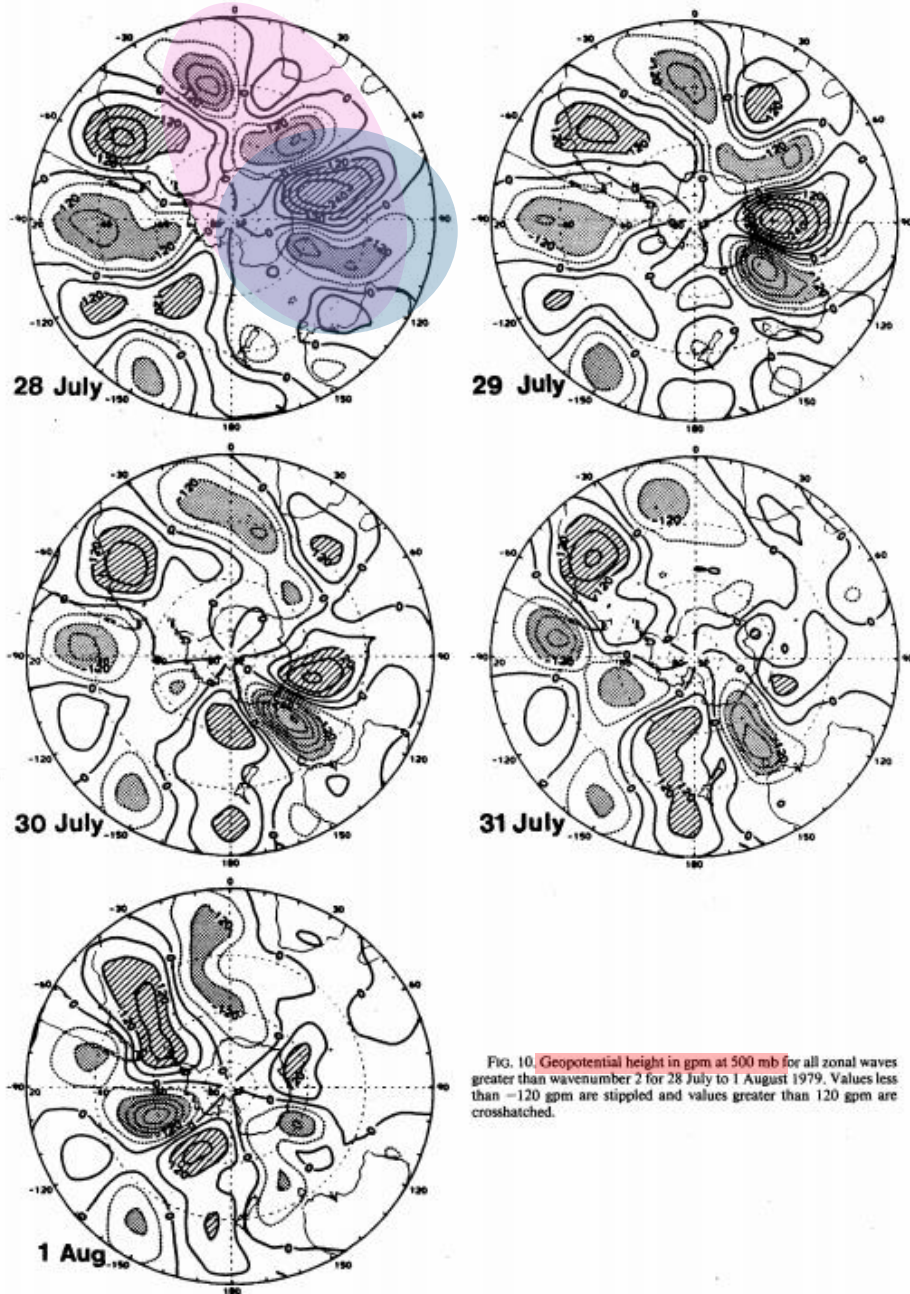


Maior atividade do Atlântico até o Oceano Índico



Maior atividade do Atlântico até o Oceano Índico

Alongamento meridional das perturbações

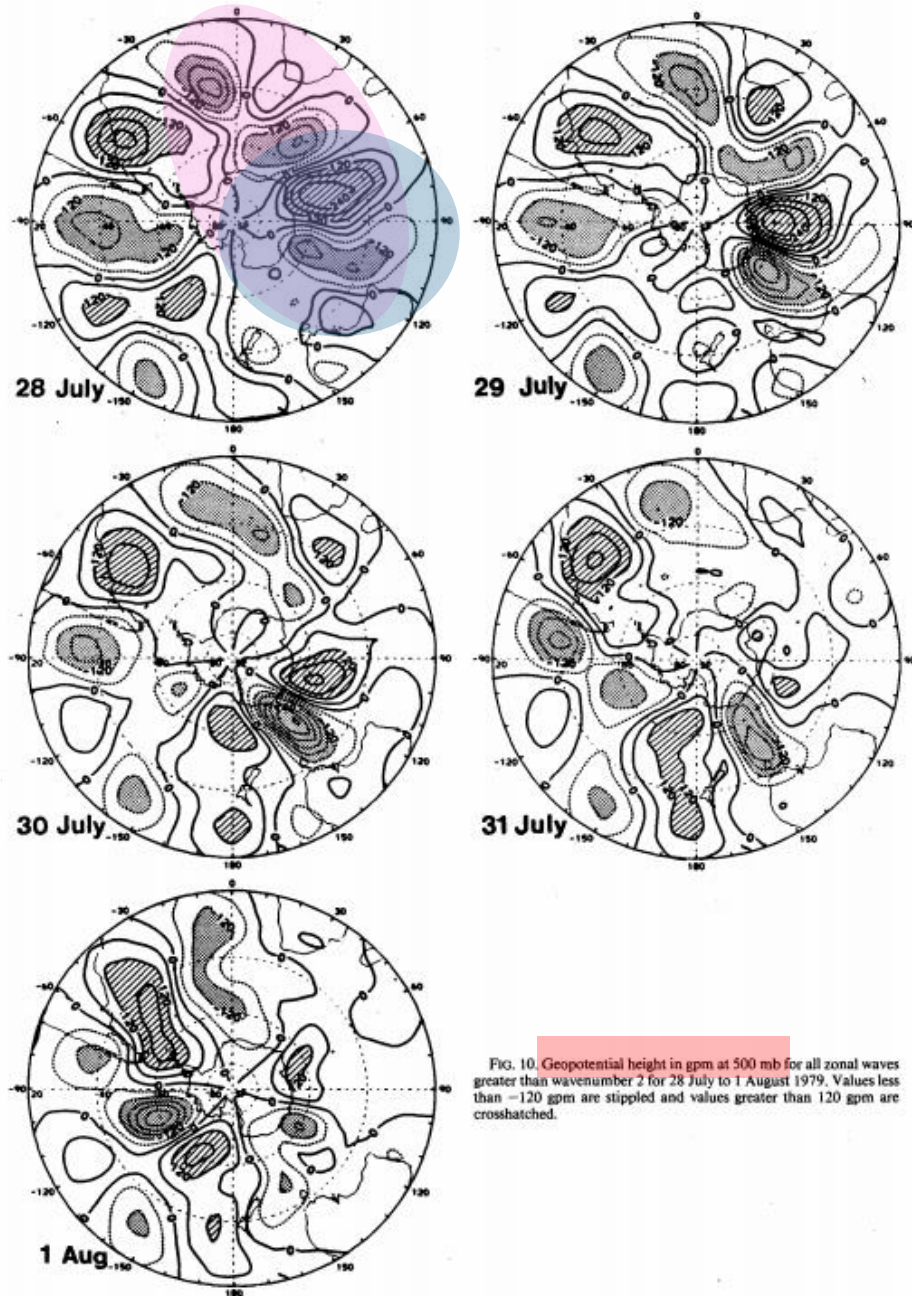




Maior atividade do Atlântico até o Oceano Índico

Alongamento meridional das perturbações

Movimento para leste



# DIAGNÓSTICOS DO FLUXO LOCAL E-P

- ▶ Interesse: forçante dos transientes no fluxo zonal médio durante eventos de bloqueio

$$\nabla \cdot \mathbf{E}_u$$



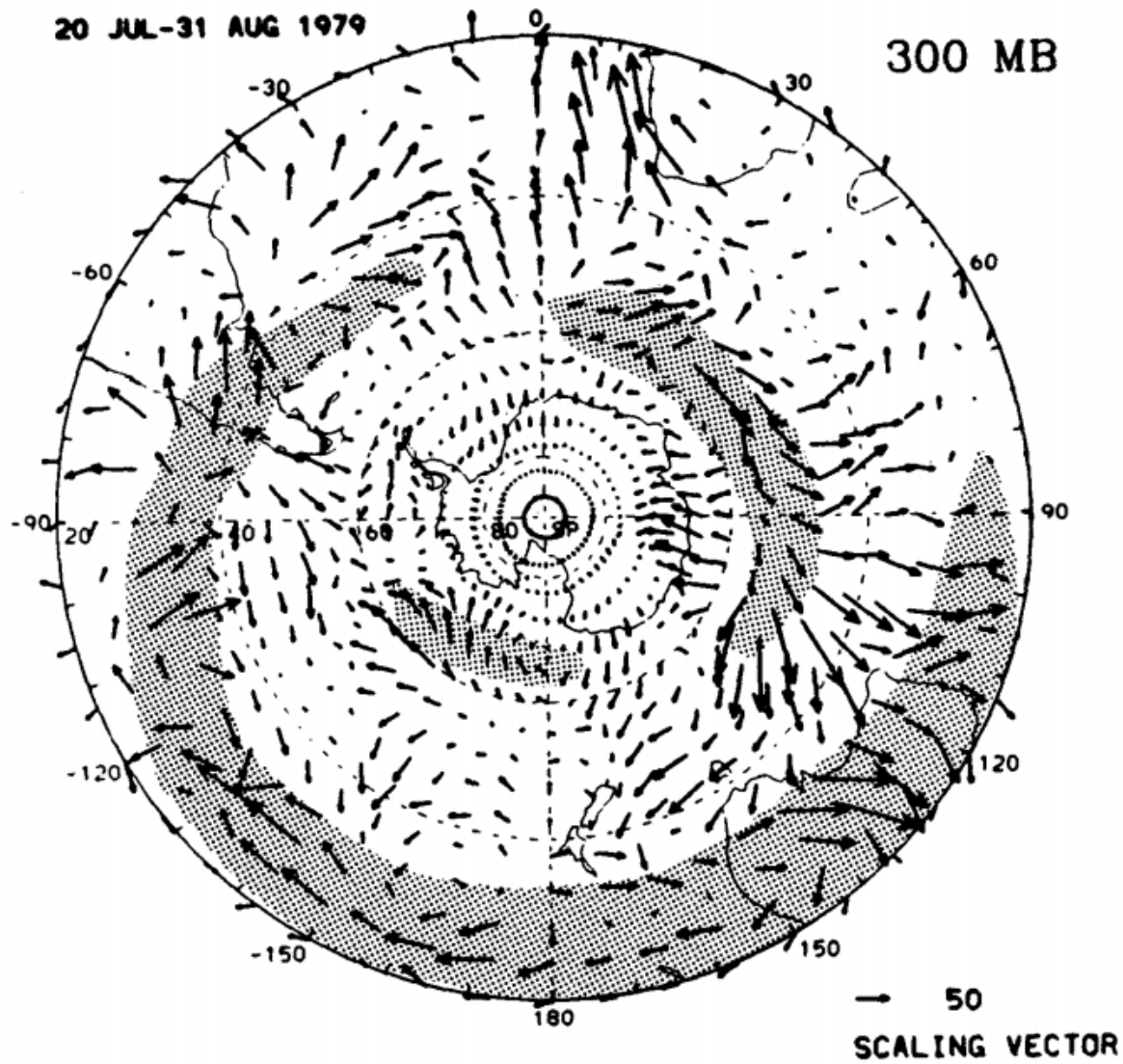


FIG. 11. Barotropic component of  $E_u$  at 300 mb for 20 July–31 August 1979 in  $\text{m}^2 \text{s}^{-2}$ . The vector scale is given at lower right. The stippled region indicates where mean winds exceeded  $30 \text{ m s}^{-1}$  over the same interval.

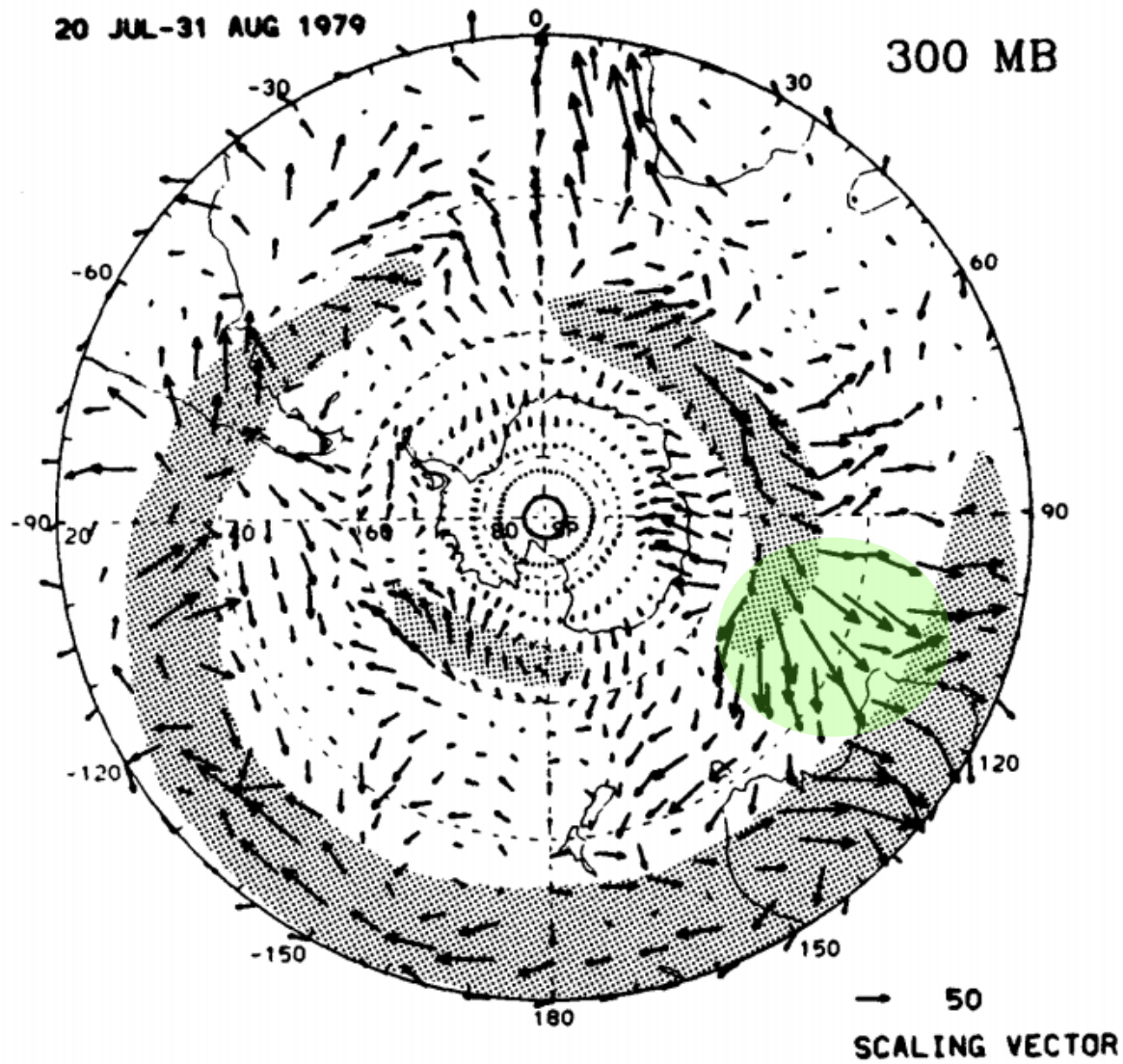
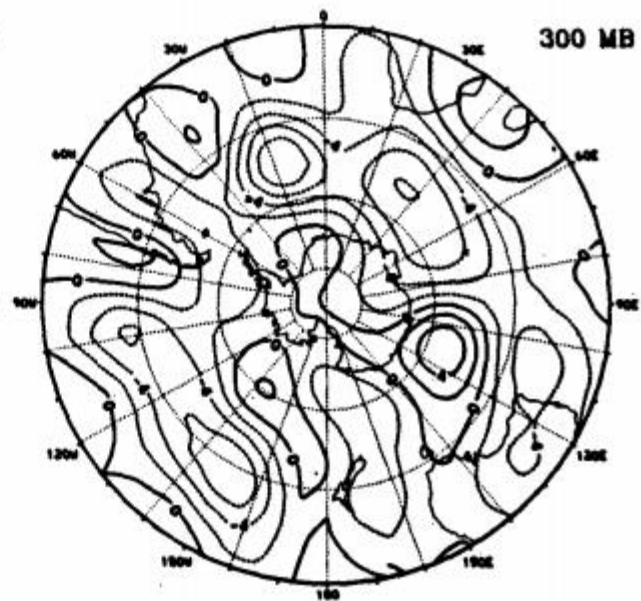
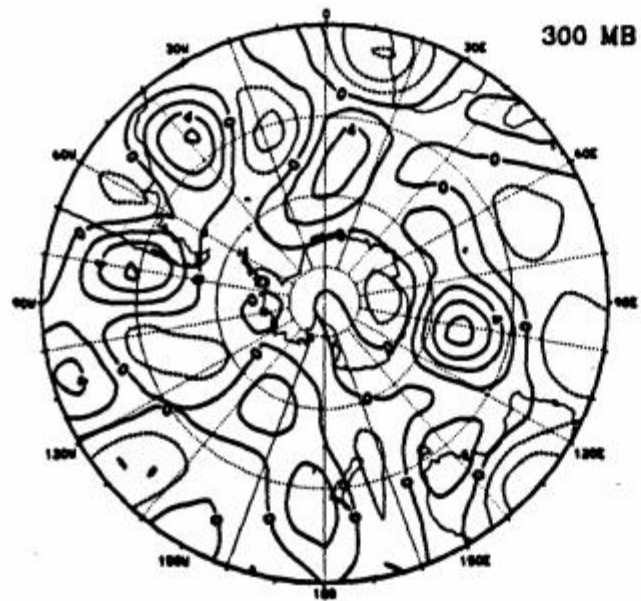


FIG. 11. Barotropic component of  $E_u$  at 300 mb for 20 July–31 August 1979 in  $m^2 s^{-2}$ . The vector scale is given at lower right. The stippled region indicates where mean winds exceeded  $30 m s^{-1}$  over the same interval.

Os eddies transitentes agem acelerando o fluxo onde as setas divergem (ex: storm-track 50°S)

HORIZONTAL E-P FLUX DIVERGENCE M/S/DAY

VERTICAL E-P FLUX DIVERGENCE M/S/DAY



TOTAL E-P FLUX DIVERGENCE M/S/DAY

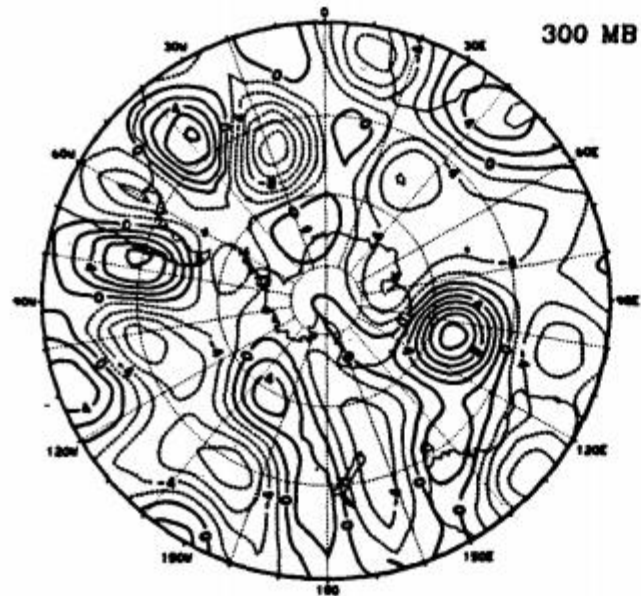


FIG. 12. Divergence of  $E_w$  at 300 mb in  $m s^{-1}/day$  for 20 July-31 August 1979. The barotropic component is given at top left, the baroclinic component at top right, and the total is given below.



HORIZONTAL E-P FLUX DIVERGENCE M/S/DAY

VERTICAL E-P FLUX DIVERGENCE M/S/DAY

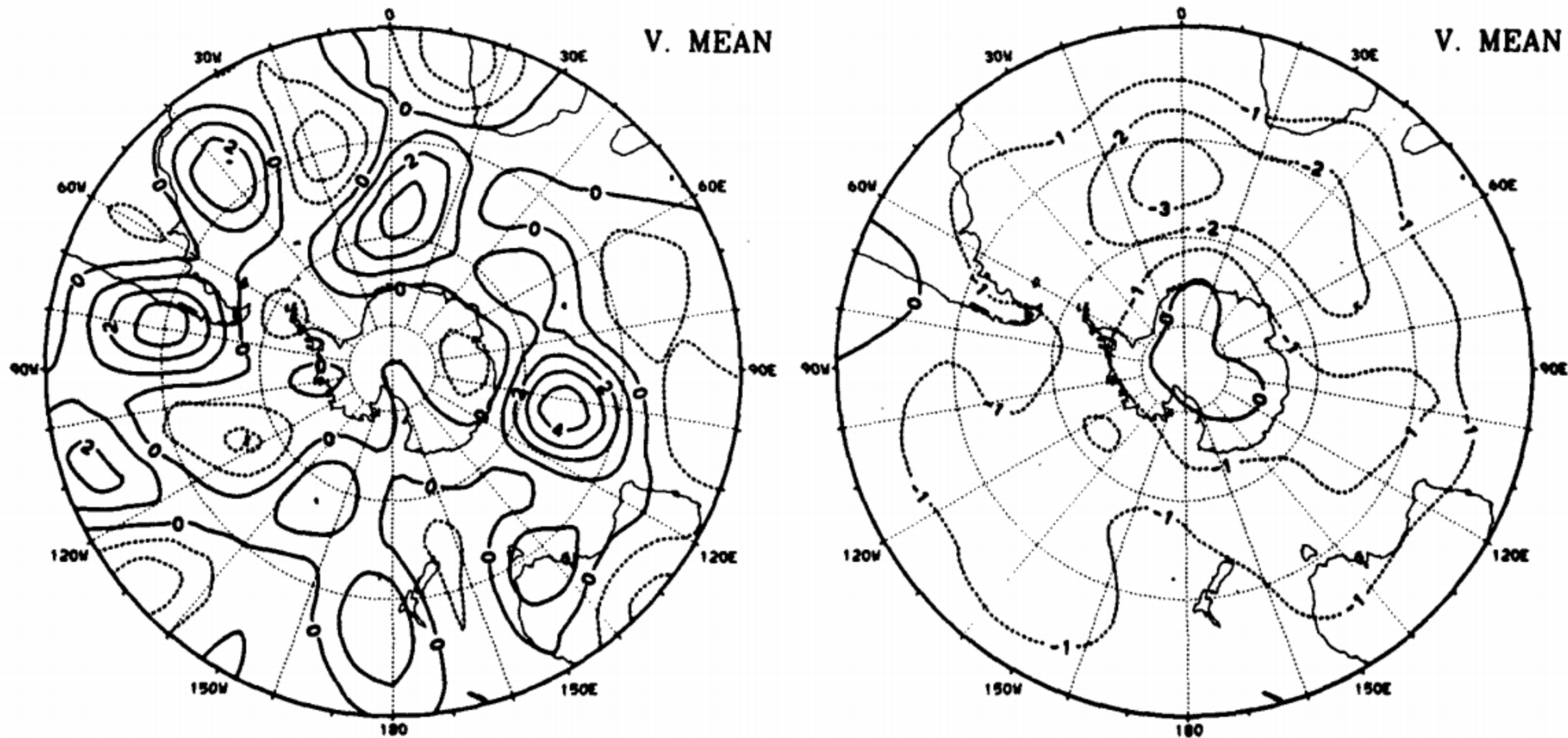
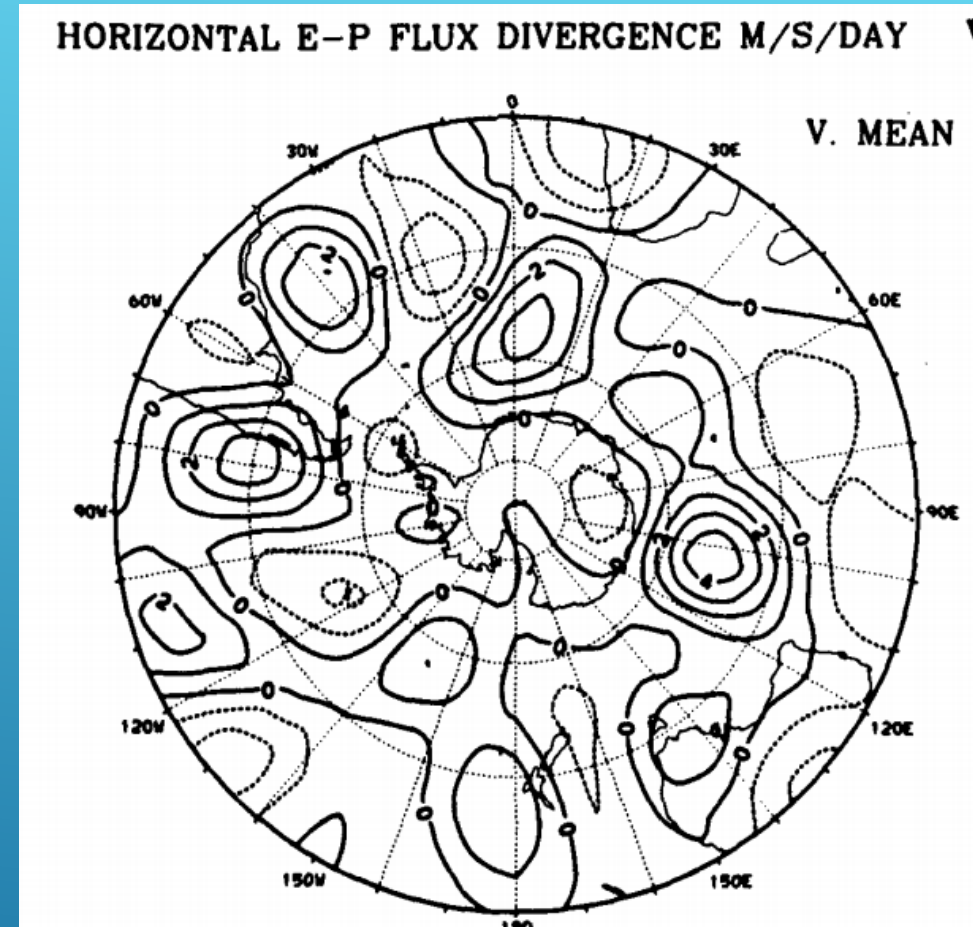
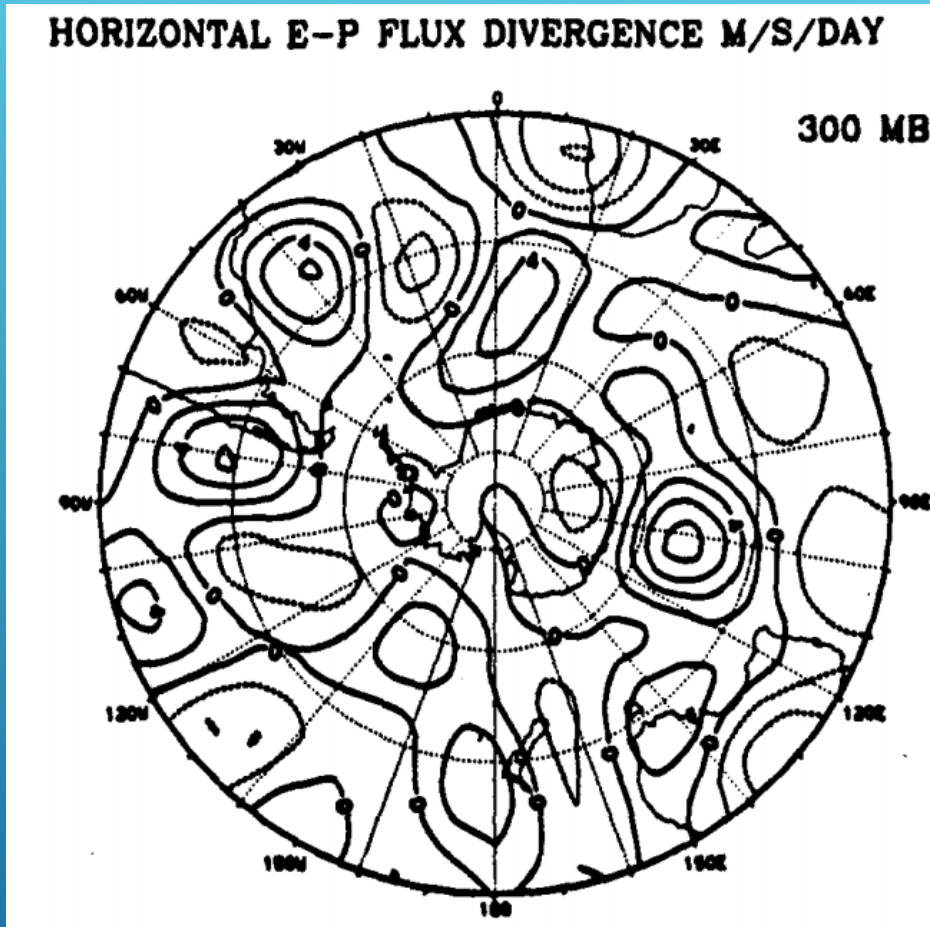


FIG. 13. Vertical means of the barotropic (left) and baroclinic (right) components of  $\nabla \cdot \mathbf{E}_u$  in  $\text{m s}^{-1}/\text{day}$  for 20 July–31 August 1979.

## Semelhança



Maiores valores em 300mb

Eddies transientes agindo barotropicamente para acelerar o fluxo entre 40°S-50°S, do Atlântico a Austrália

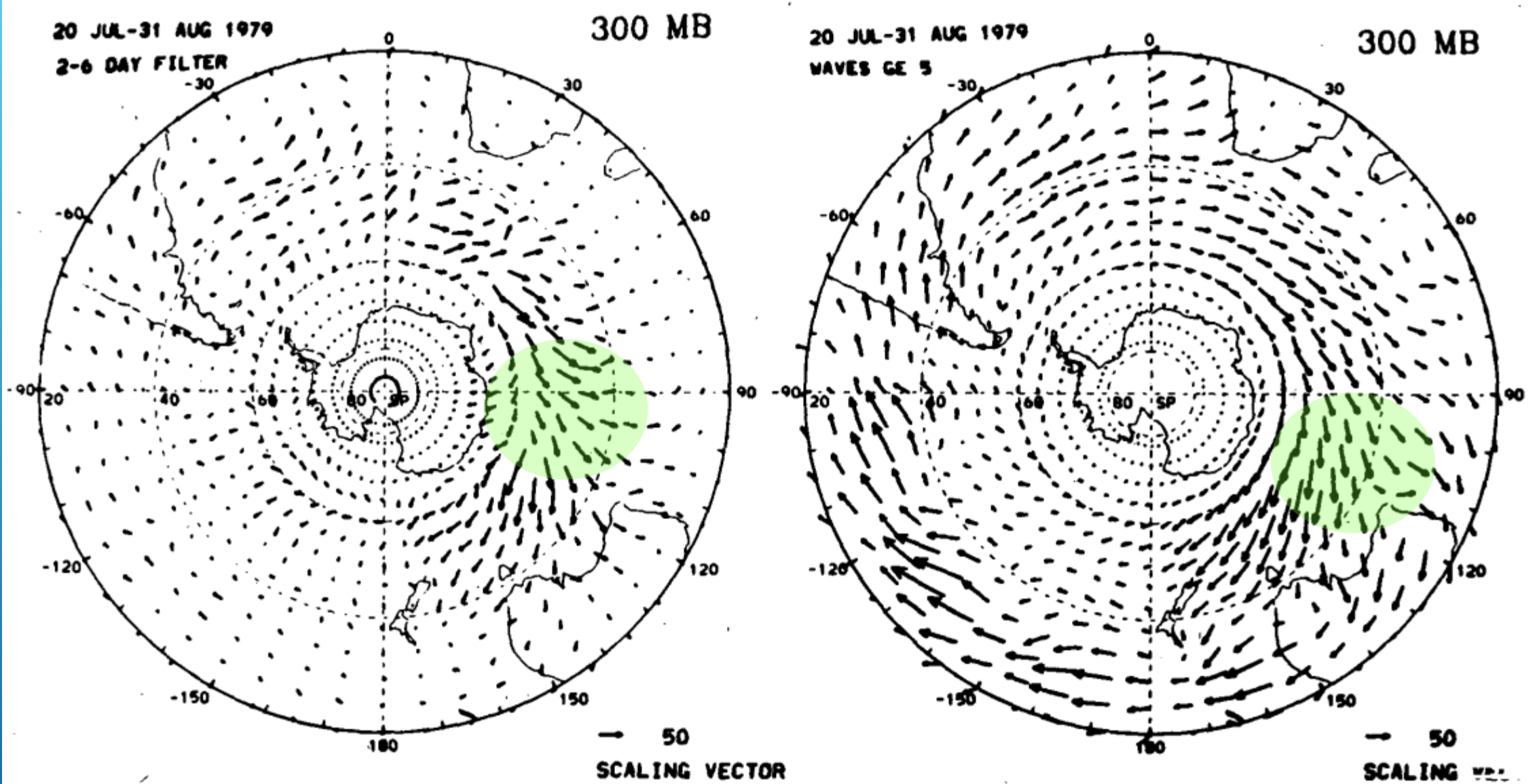


FIG. 15. Barotropic components of  $E_u$  at 300 mb for 20 July-31 August 1979 in  $m^2 s^{-2}$ . The left panel shows the 2-6 day period waves contribution and the right panel, shows the wavenumbers greater than 4 contribution.

Todos vetores apontam para leste: alongação meridional dos eddies

Divergência fora do *storm-track* no Oceano Índico (aceleração pelos eddies)



# DISCUSSÃO

- ▶ Os eddies transientes tendem a se dirigir em torno da região do anticiclone de bloqueio, seguindo o jato dividido
- ▶ E-P: eddies transientes ajudando a manter o bloqueio (desaceleram sistematicamente os ventos de oeste e aumentam a divisão do jato)
- ▶ Sul do bloqueio: n<sup>o</sup>onda 3 e 4 ; período menor que uma semana
- ▶ Norte do bloqueio: eddies transientes com maiores números zonais de onda e mais lentos (> 1 semana)
- ▶ Eddies transientes: aceleram, barotropicamente, os ventos de oeste no *storm-track* e desaceleram perto da partição do jato, ajudando a manter o bloqueio (barotropicamente e baroclinicamente)
- ▶ Origem da partição no jato?