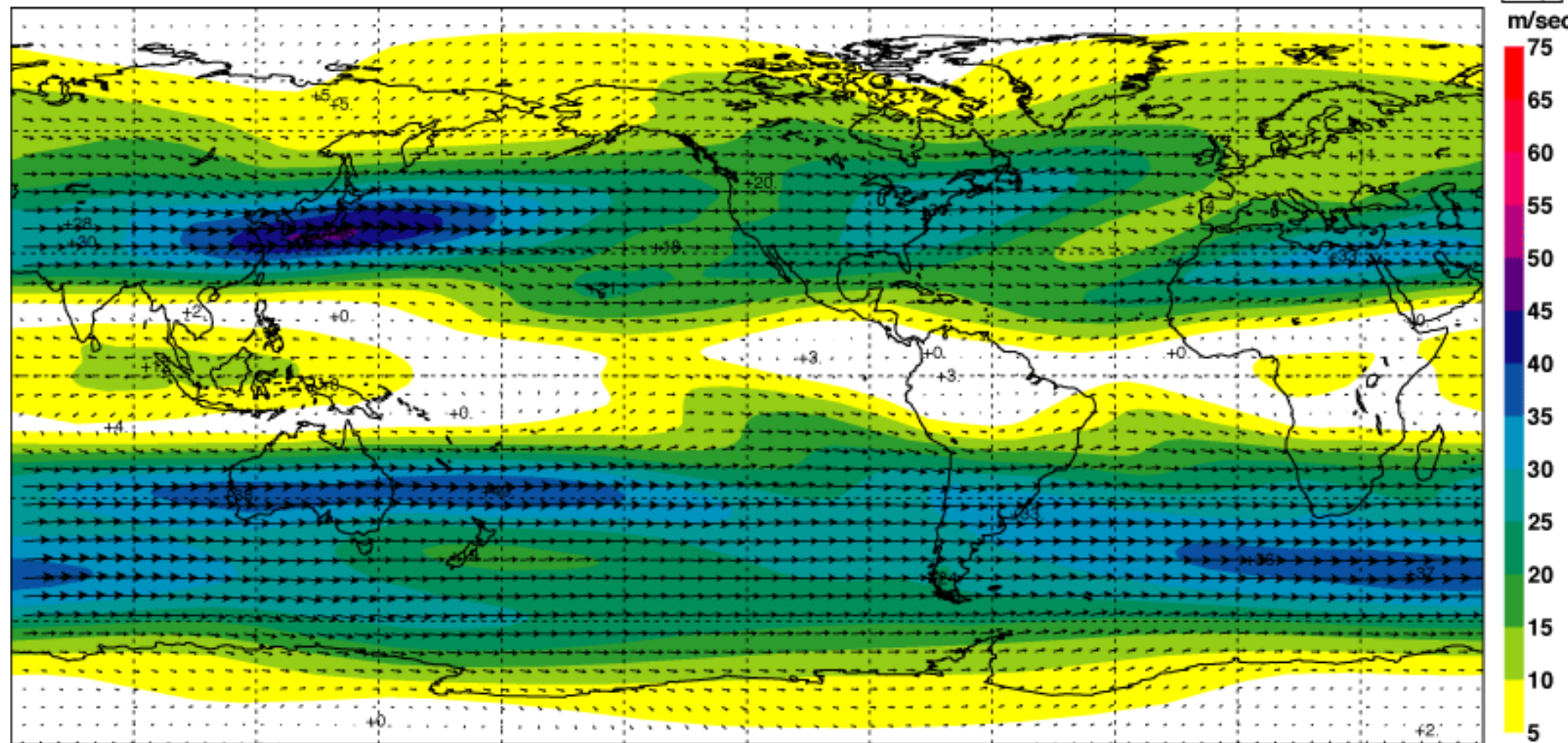


Transientes y bloqueos

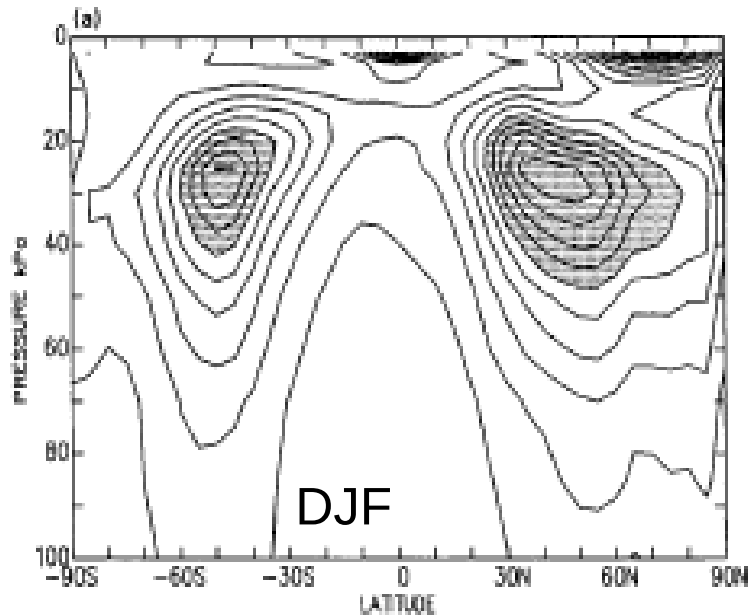
Los jets en altura están fuertemente relacionados con los transientes

Wind vector and isotachs at 200 hPa

Annual mean

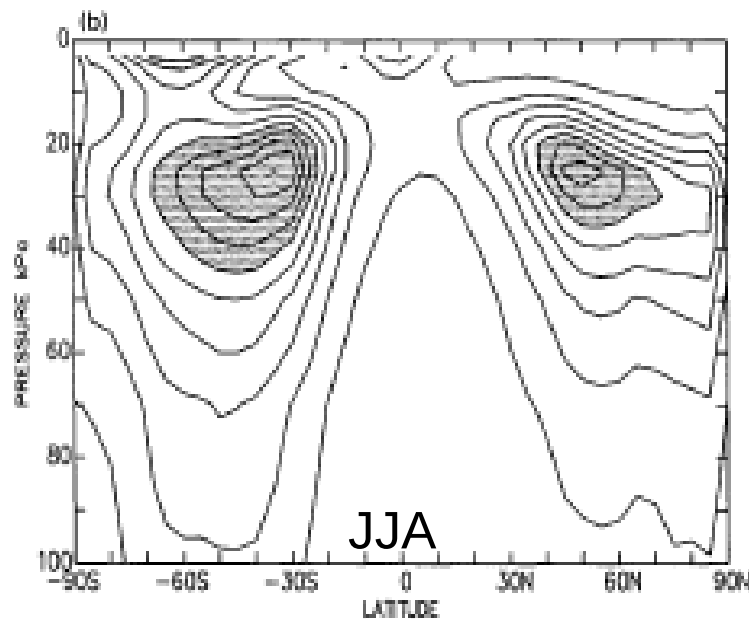


Transient Eddy kinetic energy (DJF)



Desviaciones con respecto a la media
 $u' = u - \bar{u}$

$$K = \frac{1}{2} (\overline{u'^2 + v'^2})$$



Larger in midlatitudes,
in upper levels, and
in winter hemisphere.

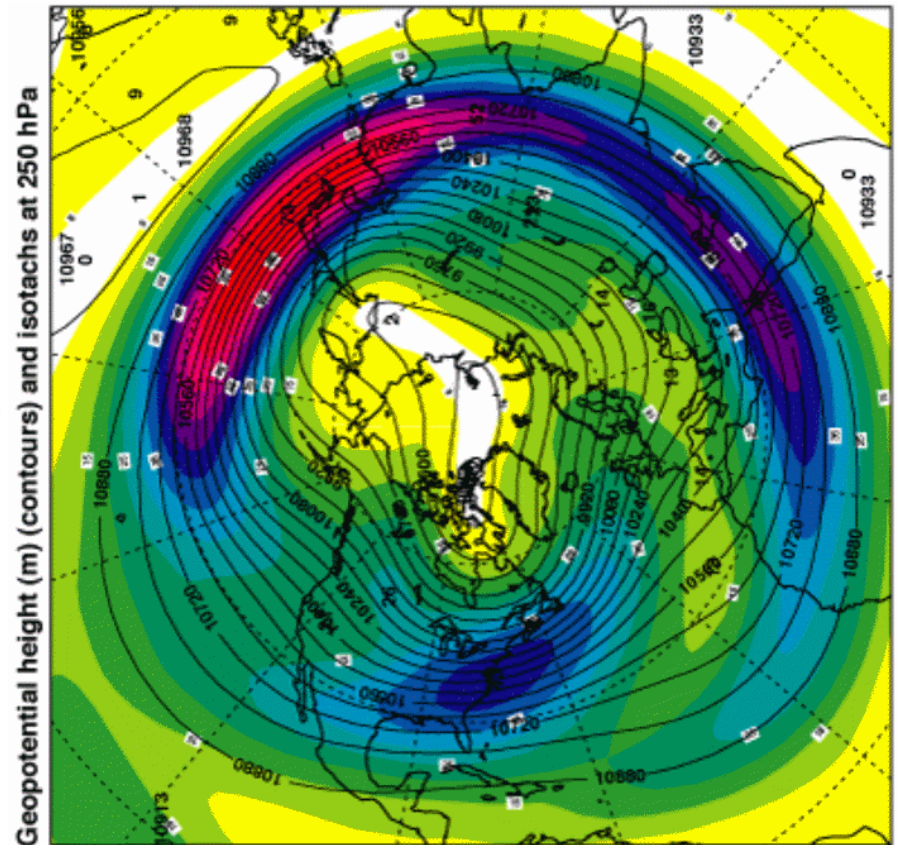
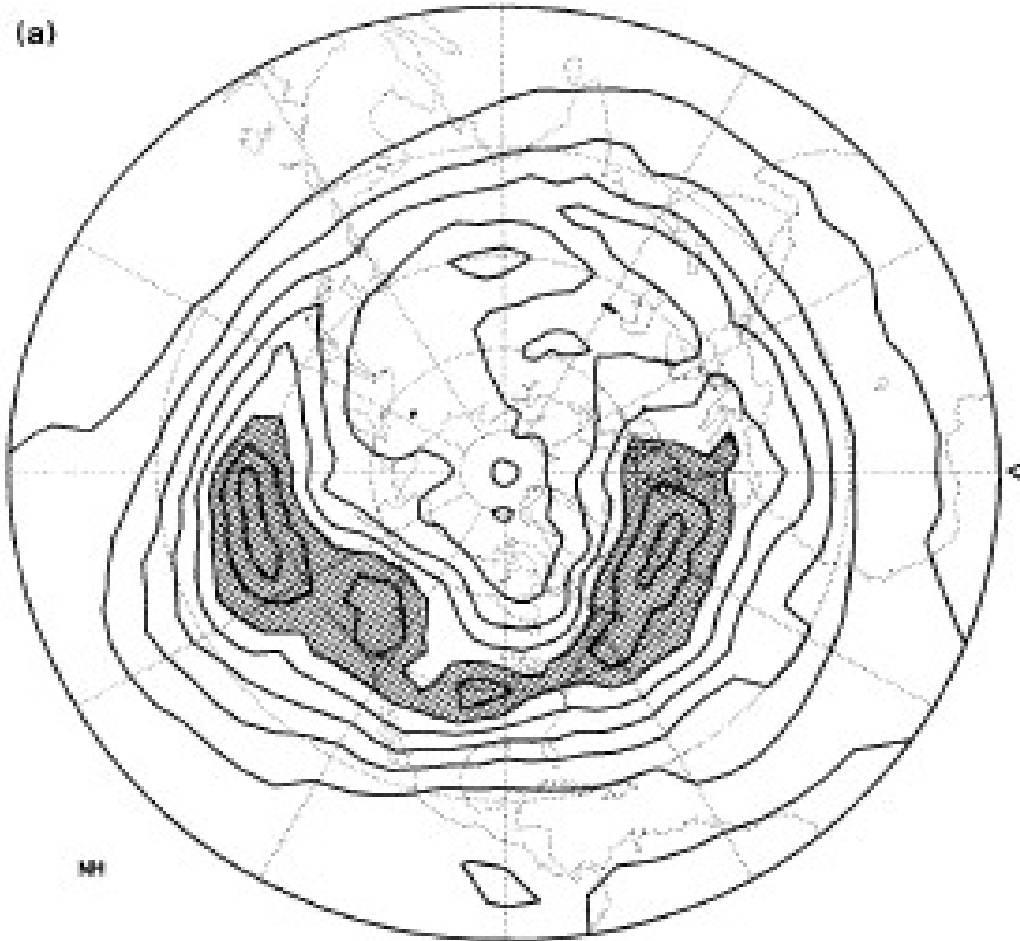
Transient Eddy kinetic energy (DJF)

$$K = \frac{1}{2} (\overline{u'^2 + v'^2})$$

Varies zonally, with maxima in jet exits.

DJF
C.I. 50m²/s²

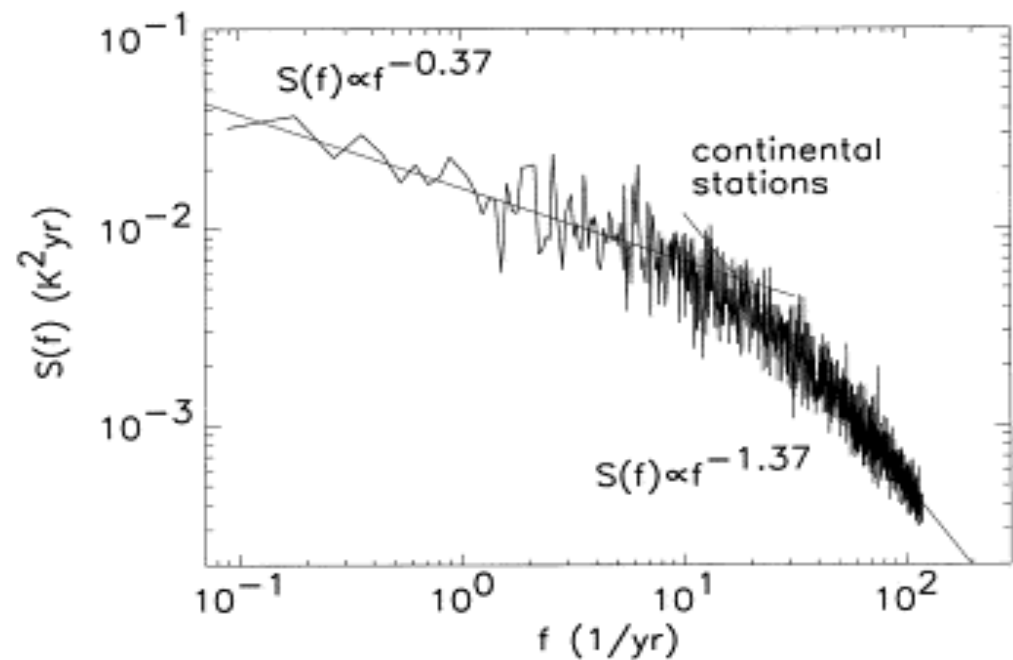
(a)



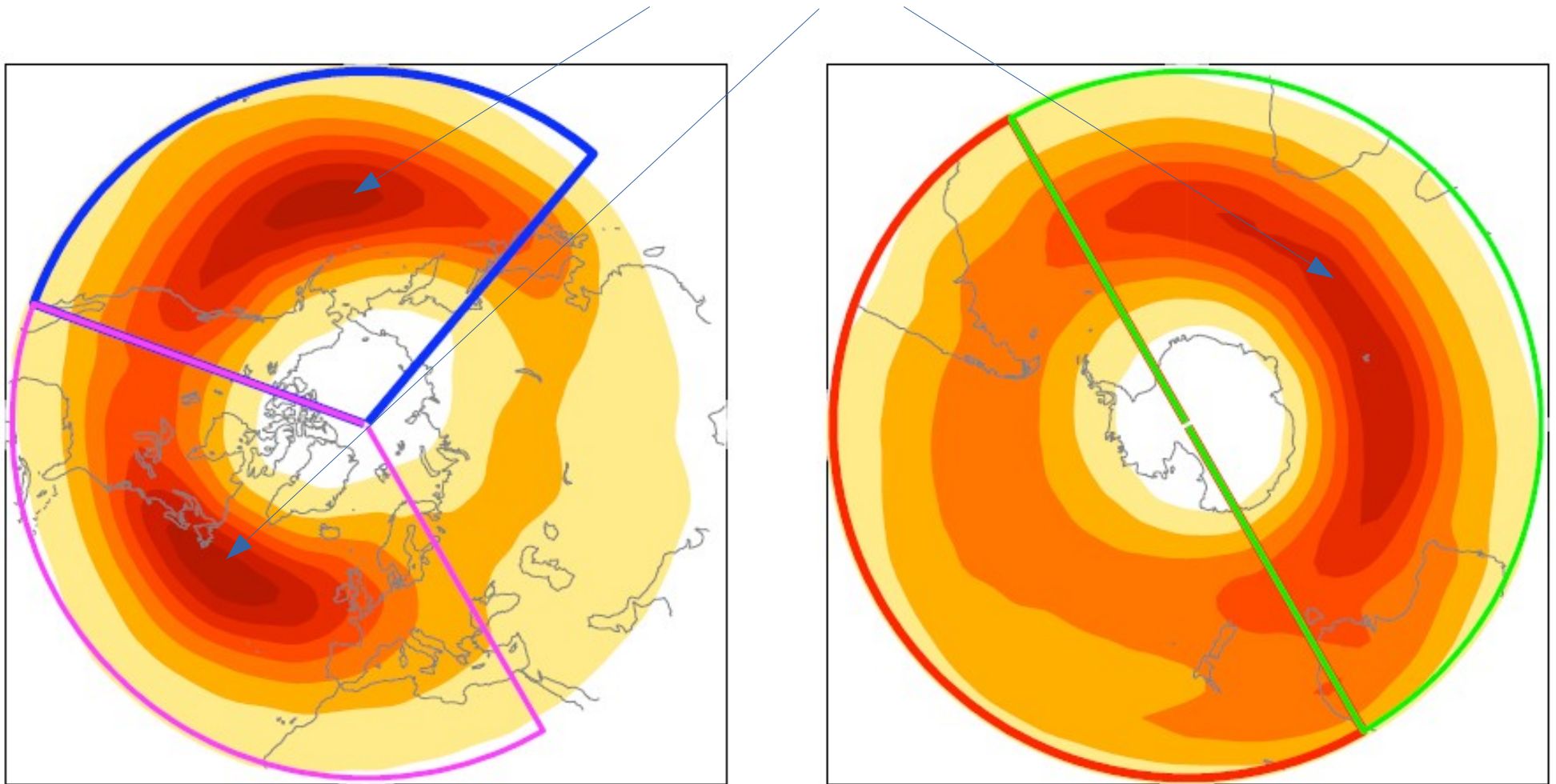
The time spectrum of transient atmospheric motion is continuous.

However, usually we divide it into two bands:

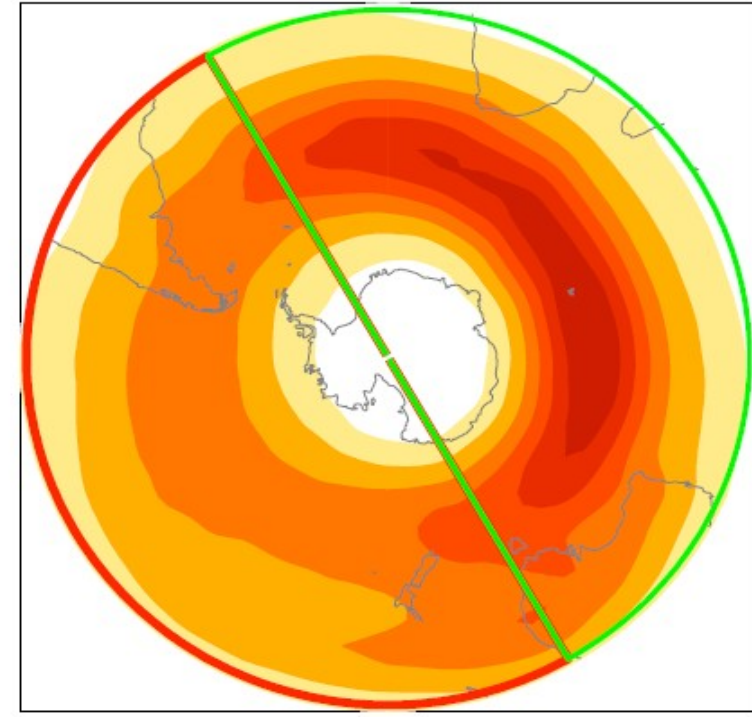
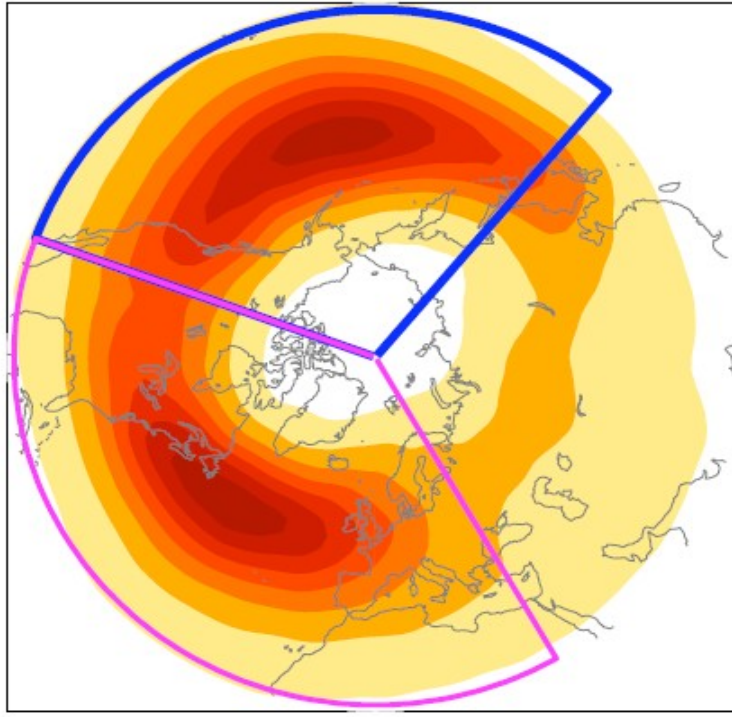
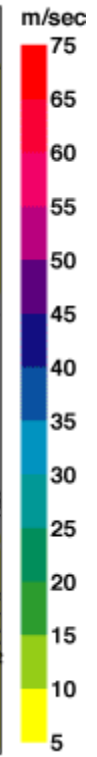
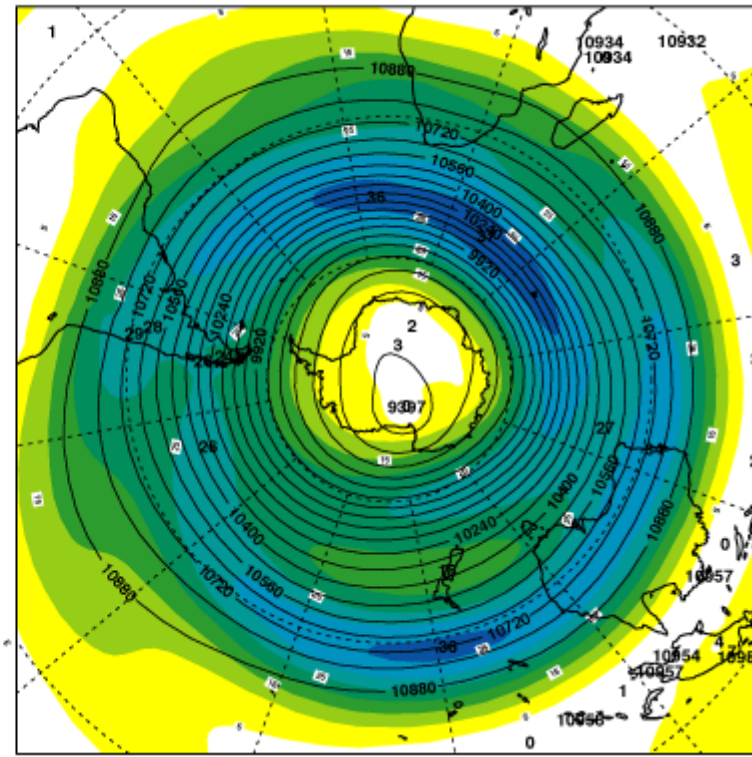
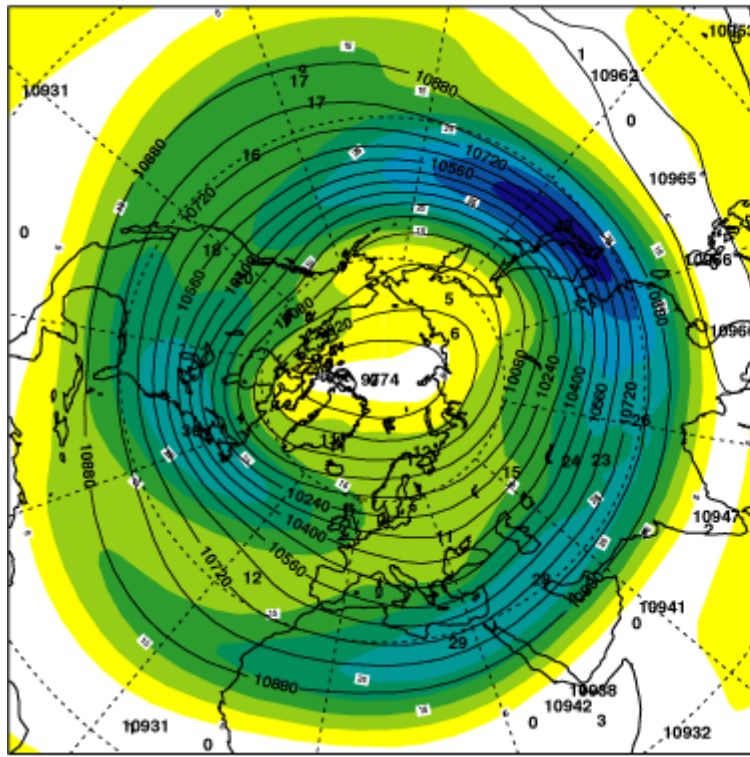
- ✓ **High frequency** (1-10 days) “synoptic”, “weather”.
Due mainly to baroclinic instability
- ✓ **Low frequency** (> 10 days).
Due to
 - Internal dynamics of atmospheric flow, nonlinear interactions between scales → inverse cascade
 - Interactions between the atmosphere and more slowly varying systems: e.g., oceans.
 - Both mechanisms may interact.



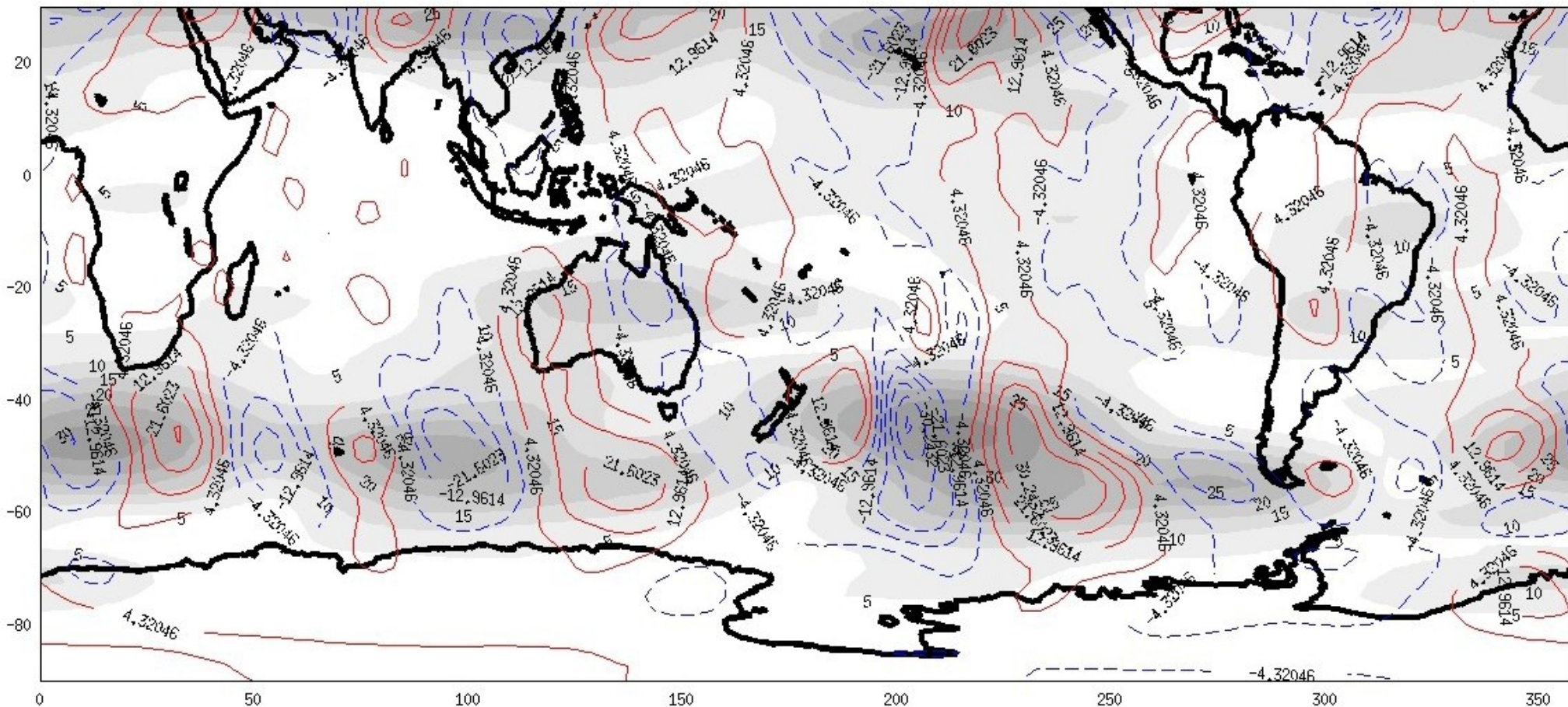
Variance of high-frequency meridional velocity perturbations (<10 days)
“storm tracks”



Geopotential height (m) (contours) and isotachs at 250 hPa

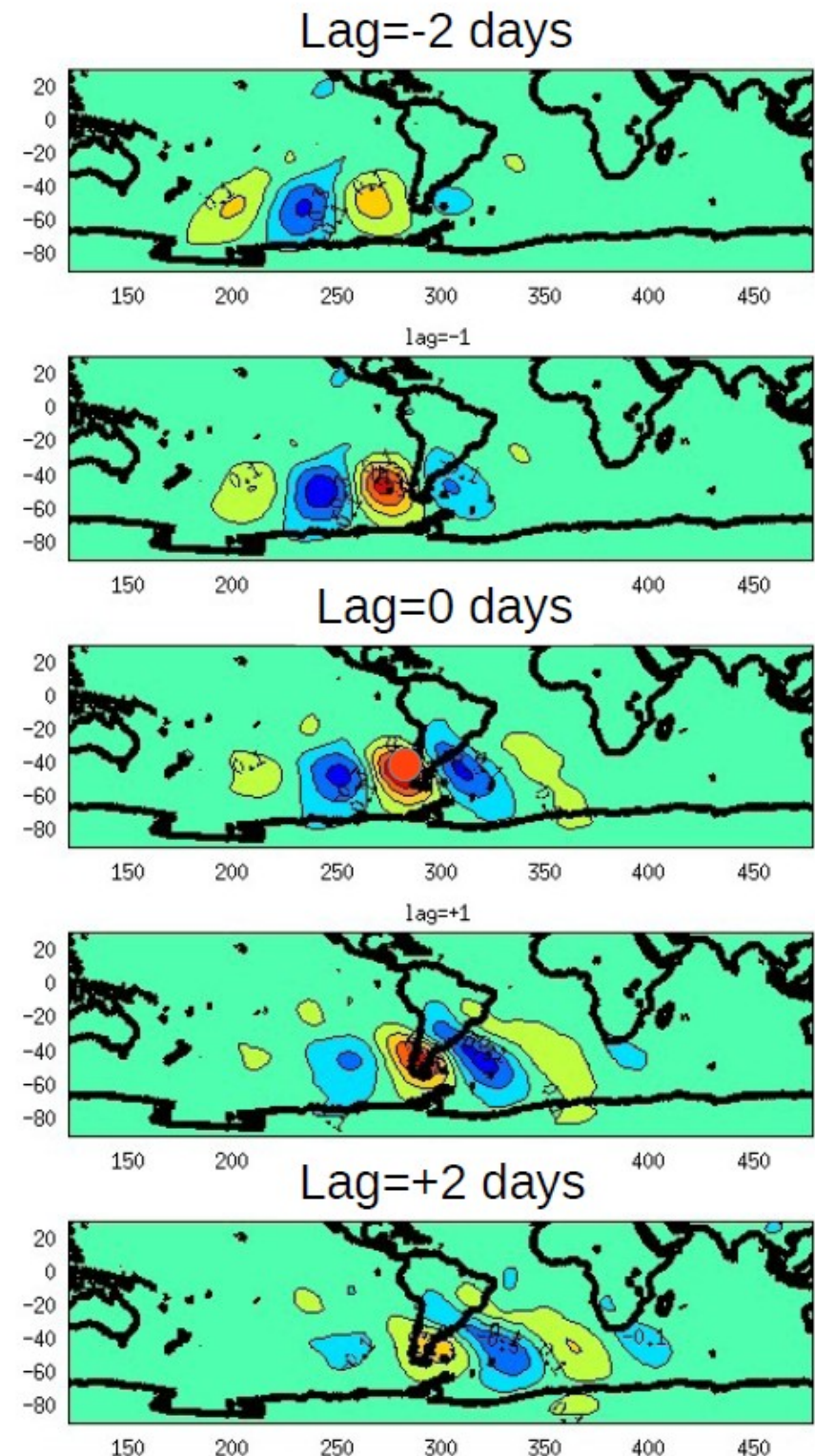


V300 en un día particular

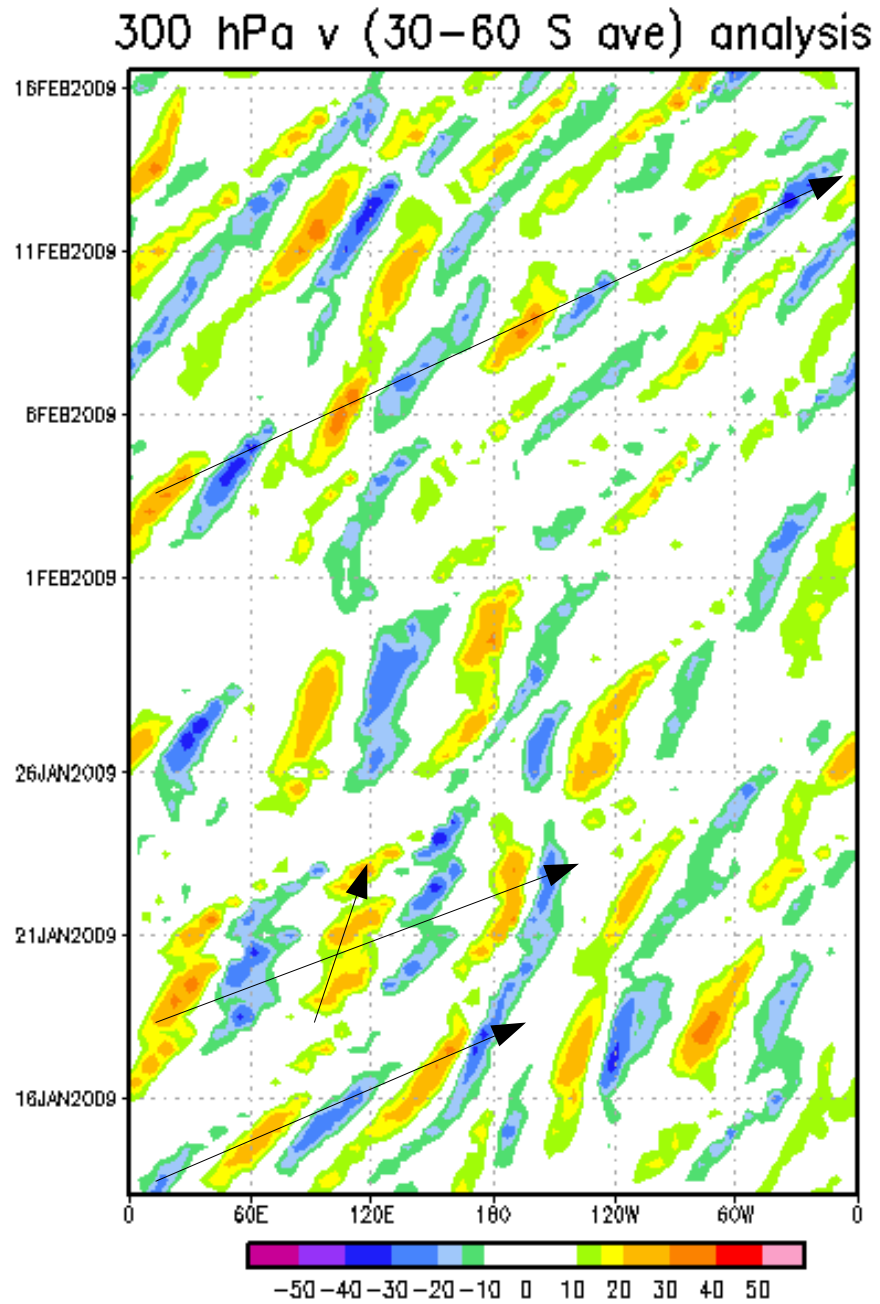


Ejemplo de mapa de correlación de punto de v300 hPa

- Muestra:
- Tren de ondas propagándose casi longitudinalmente de num. de onda ~ 6 extendiéndose aguas arriba y abajo del punto de referencia.
- El paquete de ondas se mueve más rápido que picos individuales (vel de fase < vel de grupo) \rightarrow “downward development” (Chang 1993).



Propagación de paquetes de onda



Teoria QG

Vientos ageostróficos

$$u_g \frac{du_g}{dx} = f v_a$$

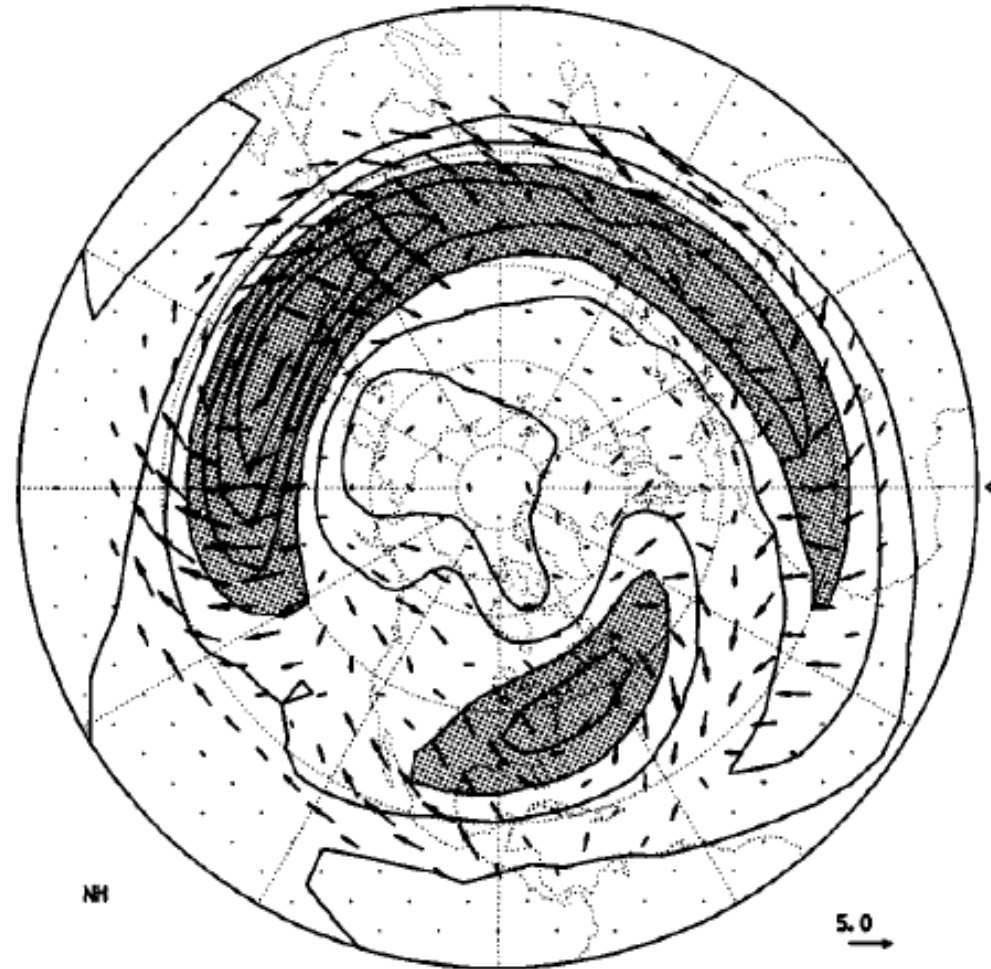


Fig. 7.13. Isotachs of the mean wind at 25 kPa for the DJF period, northern hemisphere, together with vectors of the ageostrophic wind at the same level. Contour interval 10 m s^{-1} , with values greater than 30 m s^{-1} shaded. The sample vector represents 5 m s^{-1} . Based on six years of ECMWF data.

Velocity correlation tensor

Eddy anisotropy

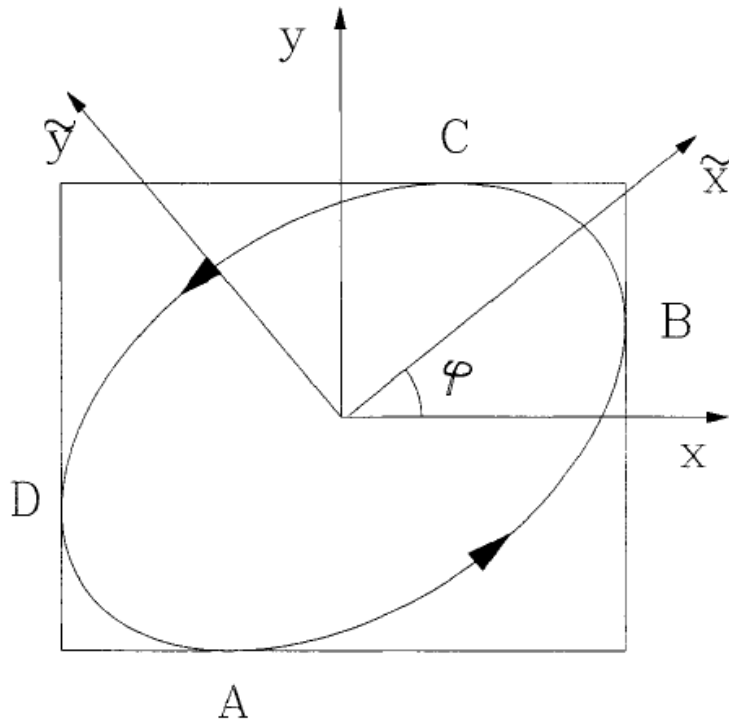


Fig. 5.4. Schematic illustration of a tilted eddy.

$$\mathbf{C} = \begin{pmatrix} \overline{u'^2} & \overline{u'v'} \\ \overline{u'v'} & \overline{v'^2} \end{pmatrix} = \begin{pmatrix} K & 0 \\ 0 & K \end{pmatrix} + \begin{pmatrix} M & N \\ N & -M \end{pmatrix}$$

$$K = (\overline{u'^2} + \overline{v'^2})/2,$$

$$M = (\overline{u'^2} - \overline{v'^2})/2$$

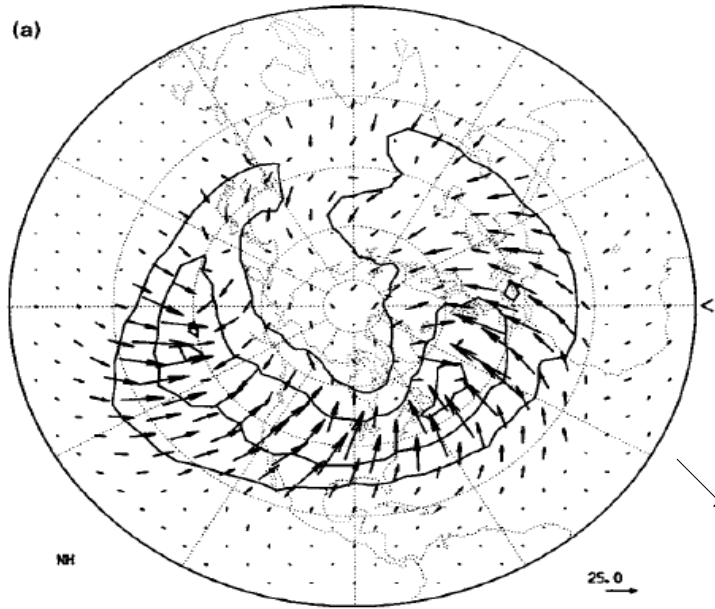
$$N = \overline{u'v'}.$$

$$\varphi = \frac{1}{2} \tan^{-1} \left(\frac{N}{M} \right),$$

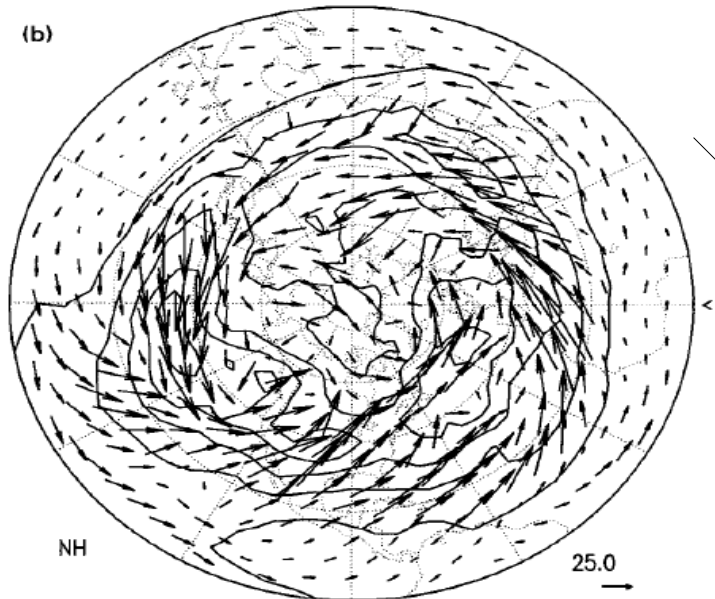
$$\hat{M} = (M^2 + N^2)^{1/2}.$$

The properties of the velocity correlation tensor can be summarized in a single plot, in which contours of K are plotted on top of vectors showing the direction of the principal axis of extension of the mean transients, and whose length is proportional to \hat{M} . Figure 7.14 compares the results for

Velocity correlation tensor



DJF, NH



Eddy anisotropy

$$\mathbf{C} = \begin{pmatrix} \overline{u'^2} & \overline{u'v'} \\ \overline{u'v'} & \overline{v'^2} \end{pmatrix} = \begin{pmatrix} K & 0 \\ 0 & K \end{pmatrix} + \begin{pmatrix} M & N \\ N & -M \end{pmatrix}$$

$$K = (\overline{u'^2} + \overline{v'^2})/2, \quad M = (\overline{u'^2} - \overline{v'^2})/2$$

$$N = \overline{u'v'}, \quad \varphi = \frac{1}{2} \tan^{-1} \left(\frac{N}{M} \right),$$

High frequency eddies are elongated meridionally and strongest in storm track regions of Atlantic and Pacific.

Low frequency eddies are zonally elongated and eddy kinetic energy is less structured.

Figuras: Contornos de K y vector muestra la dirección del semieje mayor del eddy.

Characteristics of low frequency phenomena

- Arise from many different physical processes
- Are quasi-periodic, have broad peaks, which does not allow to clearly separate frequency bands (intraseasonal, interannual).
- The spatial structures can often be interpreted to result from localized anomalies of heating or other types of forcing which under favorable conditions can propagate.

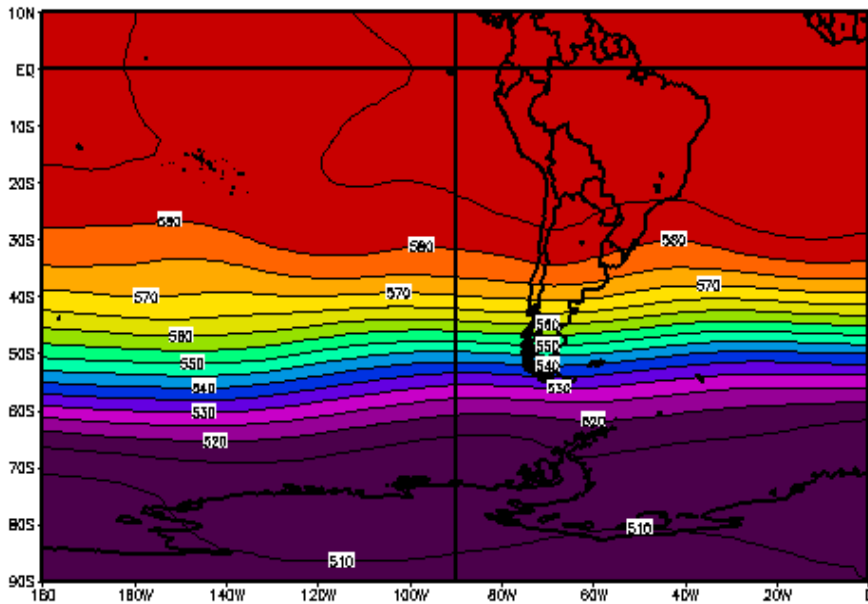
Bloqueos Atmosféricos

Definição

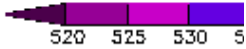
A circulação atmosférica de latitudes médias em altos níveis caracteriza-se predominantemente por um escoamento zonal de oeste que, por sua vez, favorece o deslocamento para leste e a manutenção de sistemas sinóticos, como as frentes, os ciclones e anticiclones e os *storm tracks*. Por outro lado, em condições de bloqueio, a presença de um anticiclone quase estacionário, em torno da latitude de 45°S, de grande amplitude, interrompe a progressão normal dos sistemas sinóticos para leste.

Em seu estudo clássico, Willet (1949) indicou que a circulação atmosférica de grande escala em latitudes médias tende a variar entre duas situações distintas. Na primeira prevalece o escoamento zonal (circulação de alto índice zonal), em que os distúrbios baroclínicos transientes deslocam-se livremente para leste e, na outra situação, o escoamento meridional é mais intenso (circulação de baixo índice zonal), agindo como uma obstrução para o deslocamento dos transientes. A esse segundo padrão de circulação estão associados os bloqueios atmosféricos.

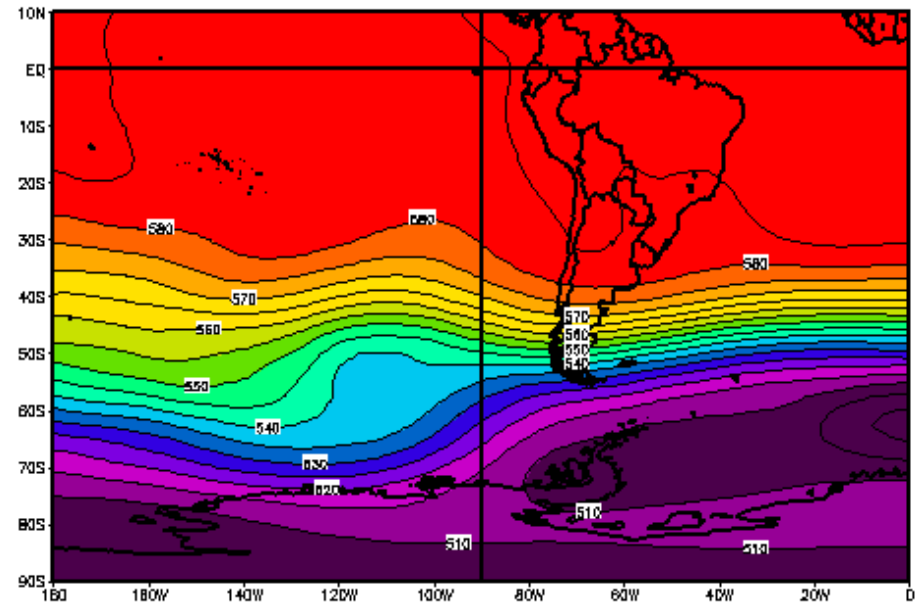
Climatologia Z500



500mb GEOPOTENTIAL HEIGHTS (dam) 14-DAY LONG TERM MEAN FOR:
DEC 15 - DEC 28



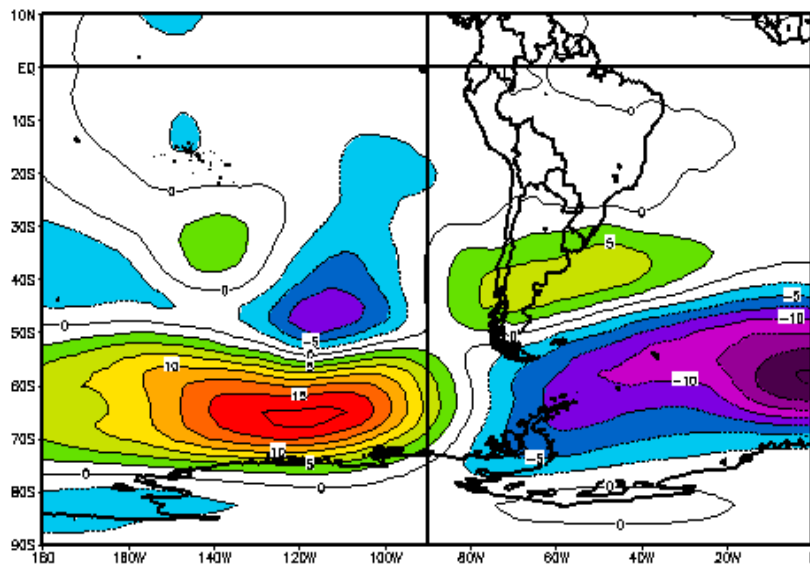
Z500 15-28/12/2013



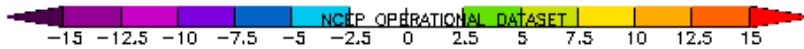
500mb GEOPOTENTIAL HEIGHTS (dam) 14-DAY MEAN FOR:
Sun DEC 15 2013 - Sat DEC 28 2013



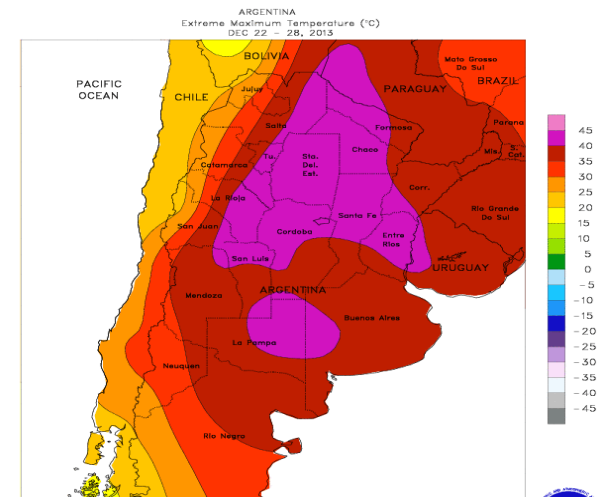
Anomalia



500mb GEOPOTENTIAL HEIGHTS (dam) 14-DAY ANOMALY FOR:
Sun DEC 15 2013 - Sat DEC 28 2013



SATa



CLIMATE PREDICTION CENTER, NOAA
Computer-generated contour
Based on preliminary data

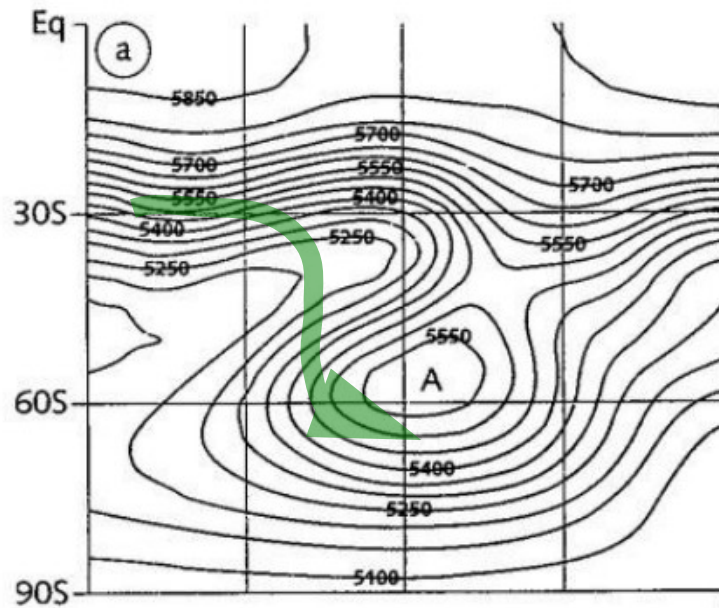


Na investigação de padrões de bloqueios, é comum ressaltar a diferença entre *blocked flow* (escoamento bloqueado) e *blocking* (bloqueio). O escoamento bloqueado está associado a um padrão de circulação que segue a determinadas condições que caracterizam a obstrução, por um anticiclone, do escoamento de oeste em latitudes médias. Por sua vez, o termo bloqueio denomina um padrão de escoamento que, além de satisfazer aos critérios que caracterizam um escoamento bloqueado, apresenta também um caráter persistente. Descrevem-se alguns critérios de identificação de bloqueios a seguir.

Tipicos patrones de bloqueo

COL=cutoff Low = Baja segregada

Patrón Omega



Patrón Dipolo/Rex

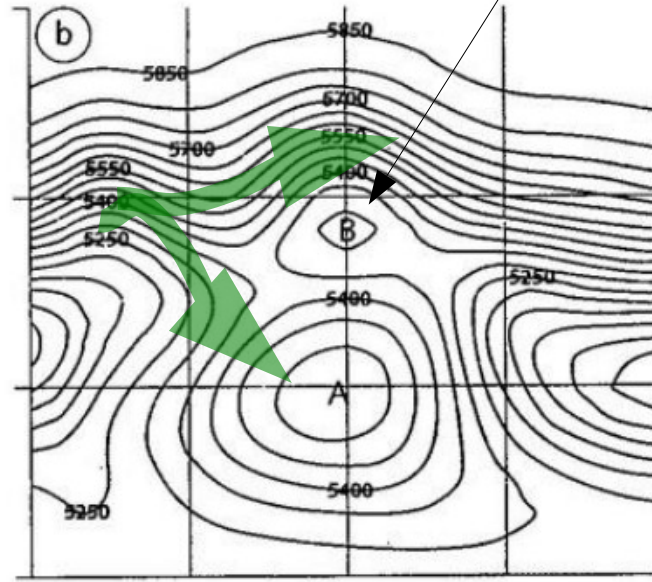


FIG. 18.1 Campos do geopotencial em 500 hPa para o HS na presença de sistemas de bloqueio: (a) Padrão Ômega; (b) Padrão Dipolo
Fonte: adaptado de Nascimento e Ambrizzi, 2002.

Ridges/Blocks Conceptual Model

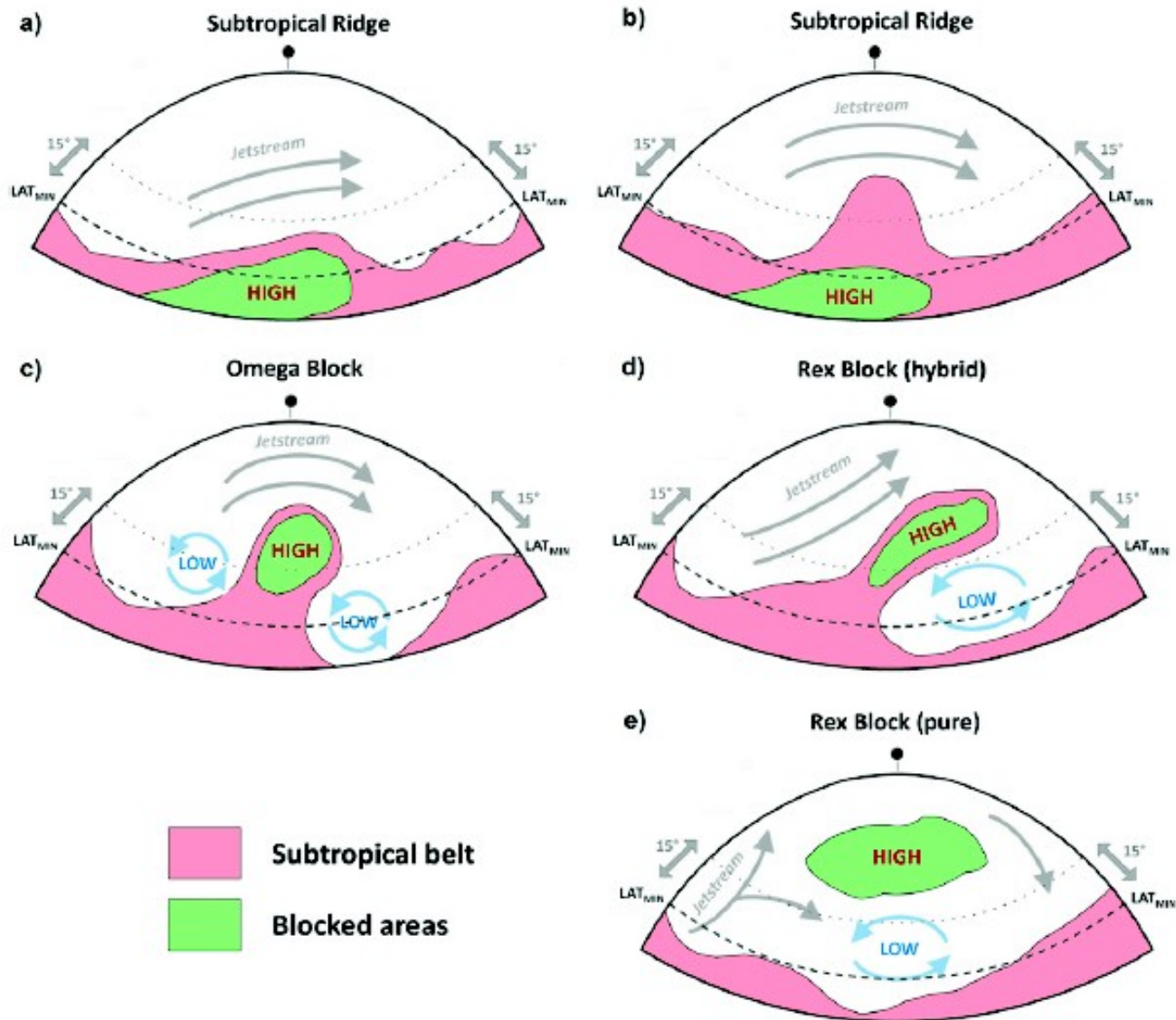


FIG. 1. Conceptual model of high pressure patterns describing a typical life cycle of an event in the NH, including the initial stages as a subtropical ridge, the development of flow reversals with omega shapes after a wave breaking, and mature phases as an isolated split-flow Rex block. Pink shading corresponds to air masses with subtropical characteristics, while green areas represent blocking of the extratropical westerlies by flow reversals in the middle troposphere. LAT_{MIN} represents the minimum latitude for detection (the zonal mean position of the subtropical belt edge). Gray and blue arrows denote typical synoptic features.

The 2010 summer mega-heatwave in Russia

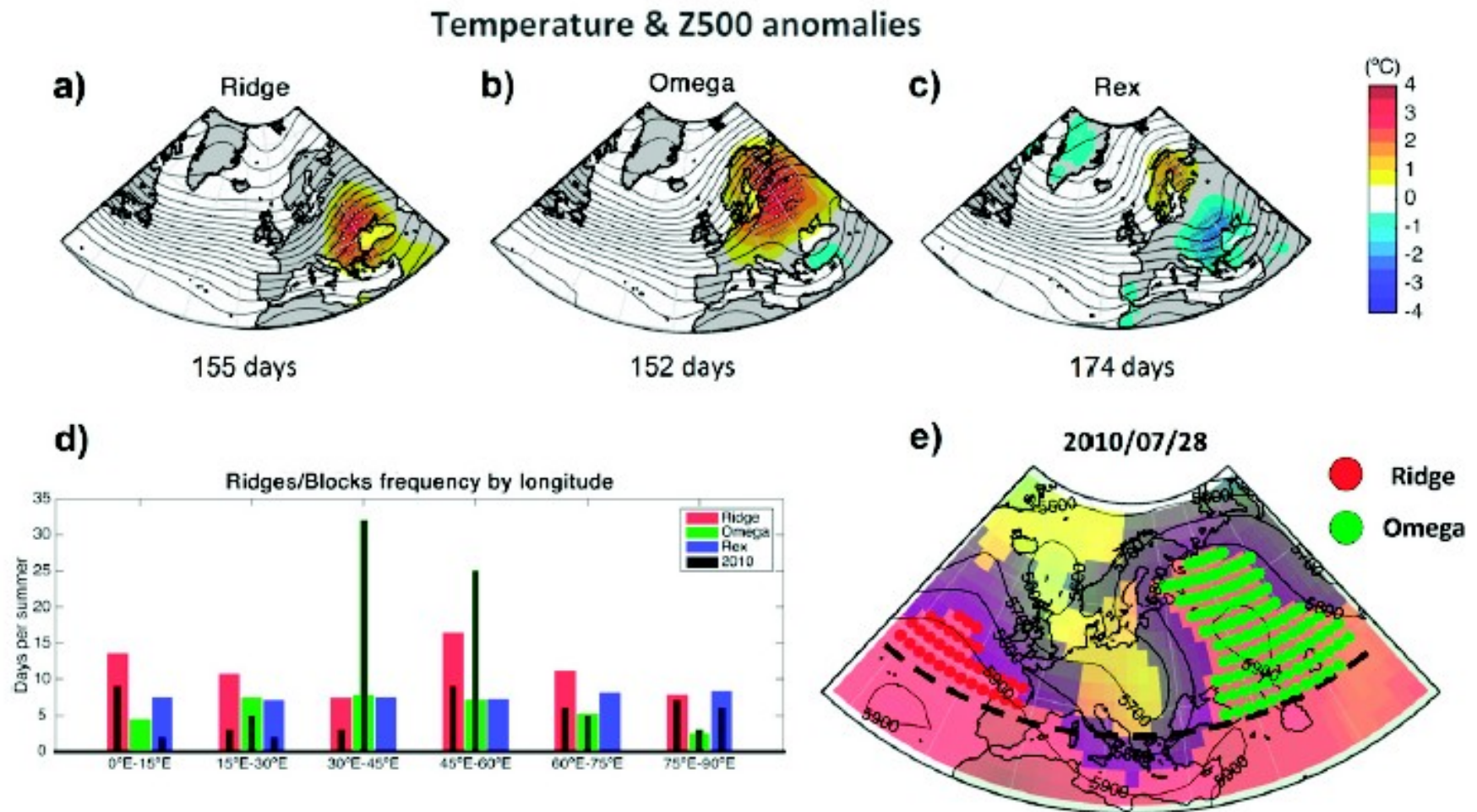


FIG. 14. European mega-heatwave of summer 2010. Composites of Z500 (black contour lines, with 25-m intervals) and 2-m temperature anomalies (shading; °C) for all summer days of 1950–2020 with (a) subtropical ridge, (b) omega block, and (c) Rex block patterns over eastern Europe (30°–60°E, and all latitudes higher than LAT_{MIN}). Light white dots represent temperature anomalies larger than one standard deviation from the seasonal mean climatology. (d) Climatological mean (colored wide bars) and 2010 (dark thin bars) summer frequencies (in days) of each type of pattern over longitudinal sectors of 15° width. (e) Snapshot detection of daily structures for 28 Jul 2010. Green and red circles identify omega block and subtropical ridge patterns, respectively. Grid points shaded with purple represent areas of strong wind ($GHG > 20$ m per degree). The dashed line denotes the minimum detection latitude (LAT_{MIN}). Data source: NCEP–NCAR reanalysis.

Detección de bloqueos

Giacosa et al (2020)

- Existencia de un gradiente de altura geopotencial meridional, para alguna latitud fija (condición de longitud bloqueada)
- Al menos 3 puntos de retícula alineados meridionalmente en donde se cumpla con la condición de bloqueo.
- Persistencia temporal de la configuración indicada en los items anteriores.

Para considerar la diferencia entre los valores de altura de geopotencial a lo largo de cierta longitud, se definen dos gradientes meridionales de altura de geopotencial, Gradiente Sur de Altura de Geopotencial (GHGS) y Gradiente Norte de Altura de Geopotencial (GHGN), según la ecuación 1

$$GHGS = \frac{z500(\lambda, \phi_S) - z500(\lambda, \phi_0)}{\phi_S - \phi_0} \quad (1)$$
$$GHGN = \frac{z500(\lambda, \phi_0) - z500(\lambda, \phi_N)}{\phi_0 - \phi_N}$$

donde ϕ es la latitud a la cual se busca el bloqueo y puede tomar los valores: $\phi_S = 65^\circ S + \Delta$, $\phi_0 = 50^\circ S + \Delta$, $\phi_N = 35^\circ S + \Delta$, siendo

$\Delta = -10^\circ, -5^\circ, 0^\circ, 5^\circ, 10^\circ$. O sea, cuando $\Delta = -10^\circ \rightarrow \phi_S = 55^\circ S, \phi_0 = 40^\circ S$ y $\phi_N = 25^\circ S$, y λ varía en el dominio fijado. Considerando el trabajo de Alessandro (2014), se utilizaron dos bandas de longitudes para caracterizar los bloqueos:

- Pacífico Atlántico Sur - PAS: $95^\circ W - 65^\circ W$
- Atlántico Sur - ATS: $60^\circ W - 0^\circ W$

Criterios

$$GHGS < -10 \text{ mgp/deg}$$

$$GHGN > 0$$

5 días

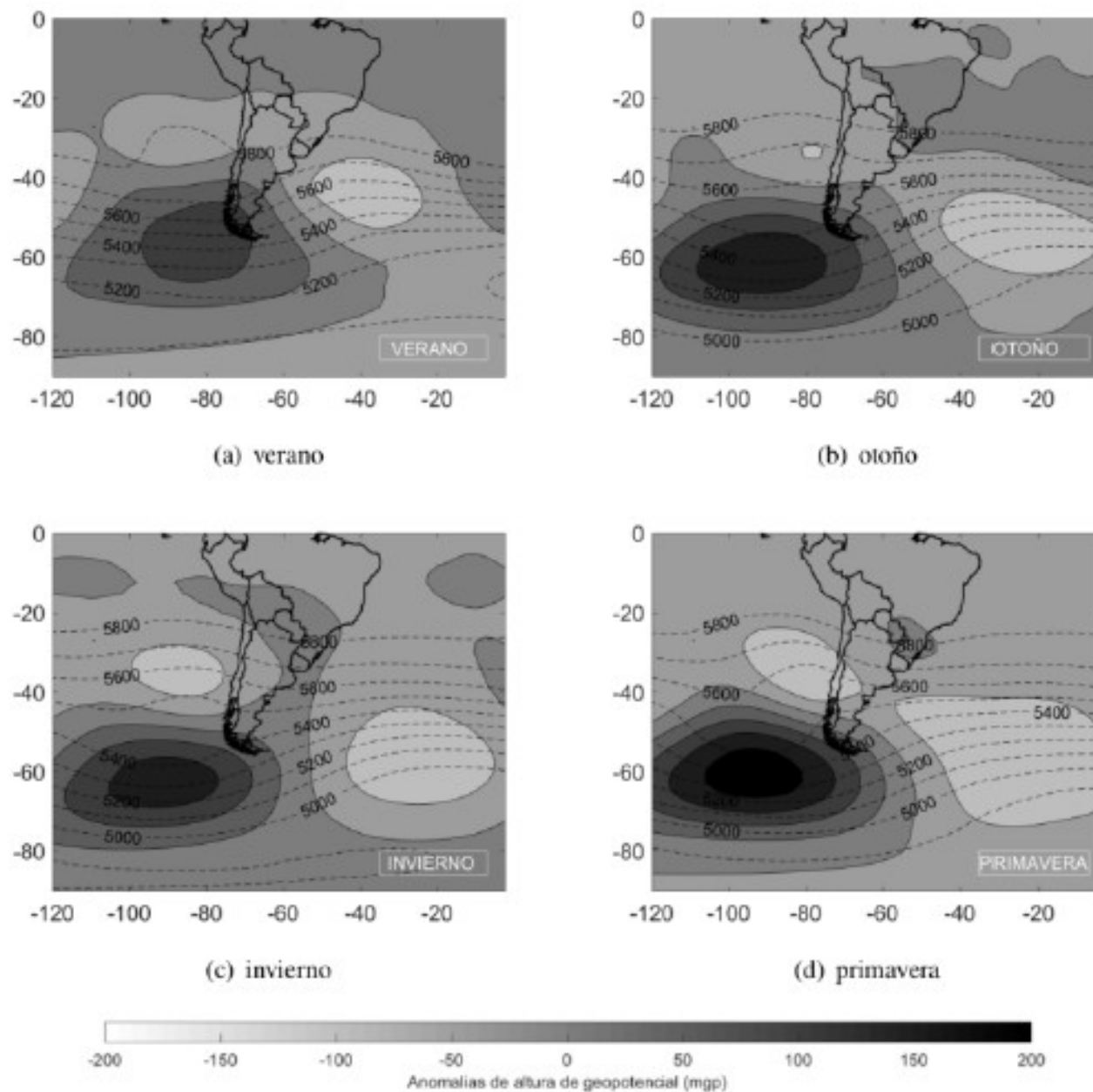
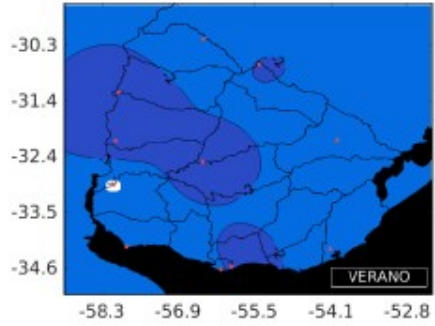


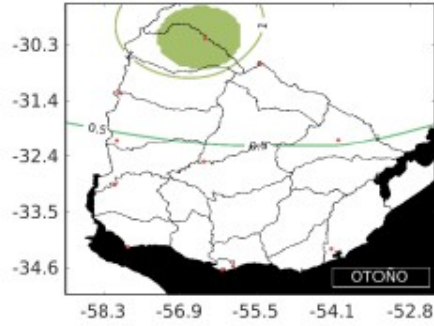
Figura 2: Composite de altura geopotencial en líneas punteadas y de su anomalía en coloreado, para bloqueos en la región PAS. (a) verano, (b) otoño, (c) invierno y (d) primavera.

TMAX

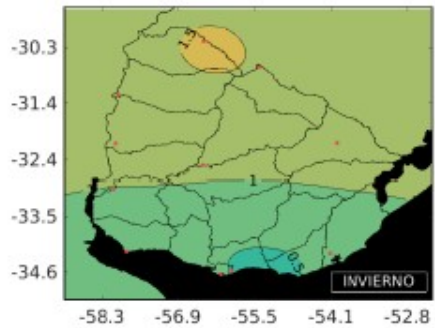
TMIN



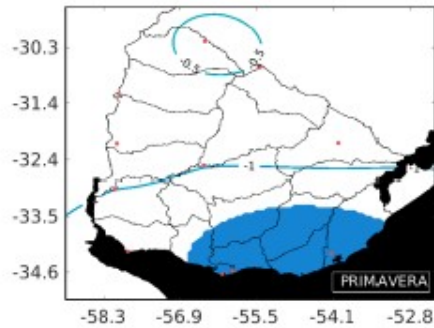
(a) verano



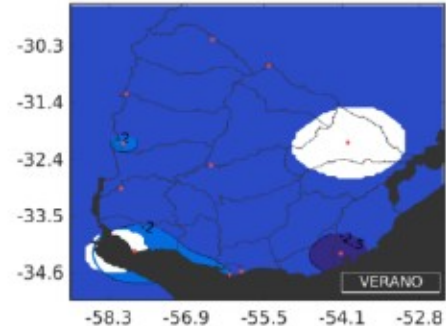
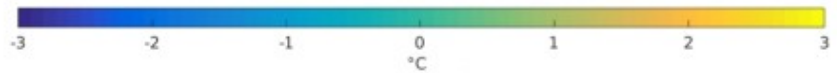
(b) otoño



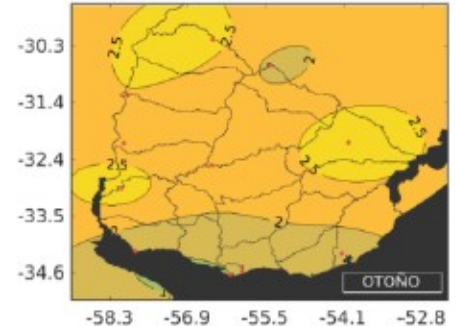
(c) invierno



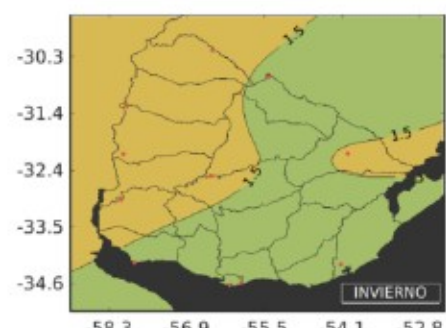
(d) primavera



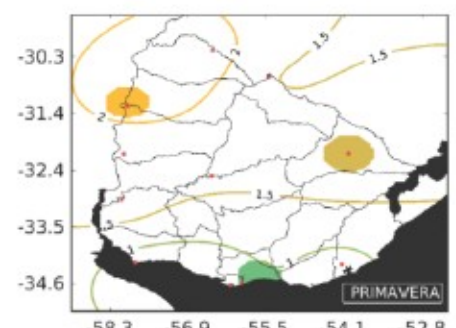
(a) verano



(b) otoño



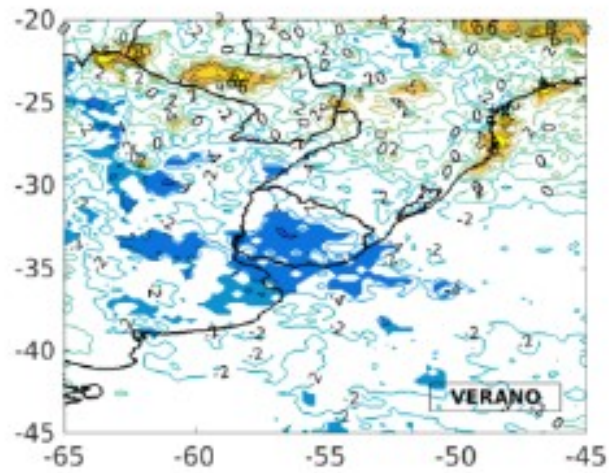
(c) invierno



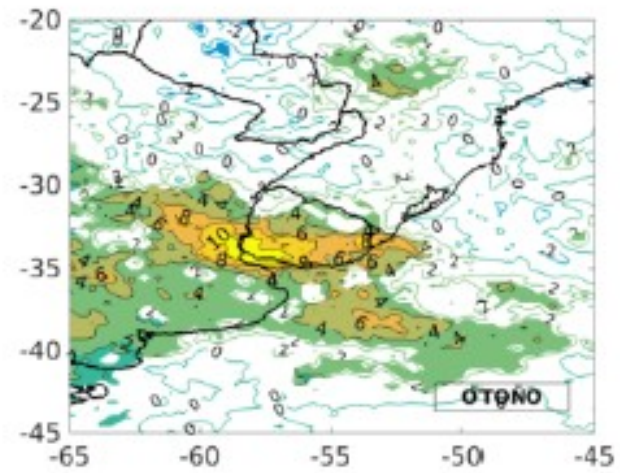
(d) primavera



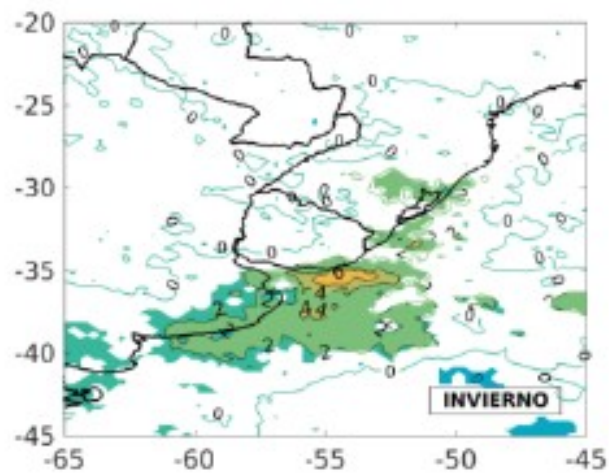
Lluvias



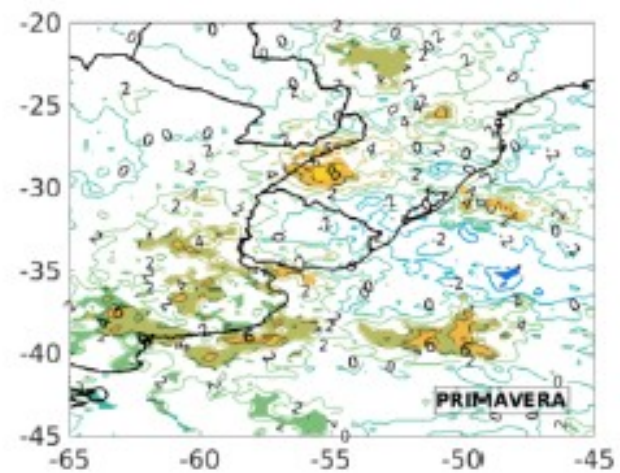
(a) verano



(b) otoño



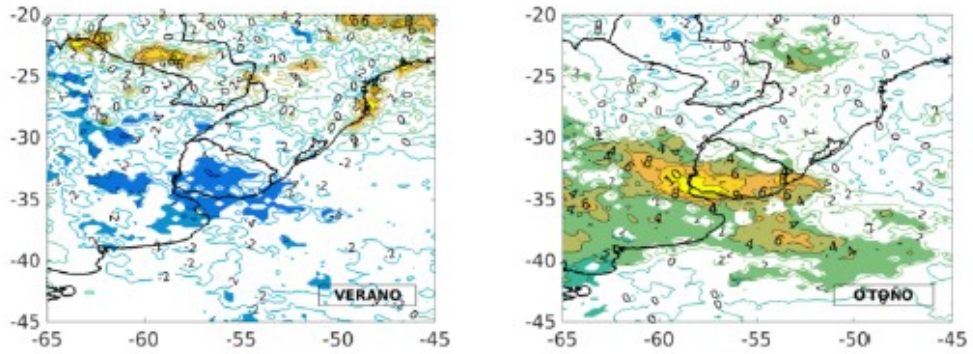
(c) invierno



(d) primavera

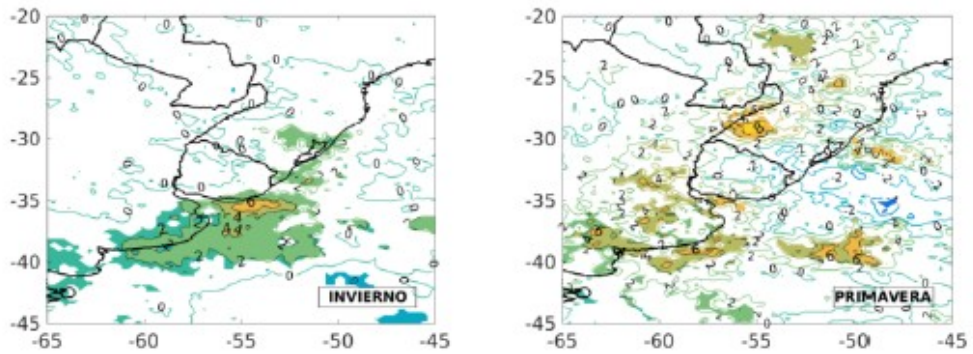


Lluvias



(a) verano

(b) otoño

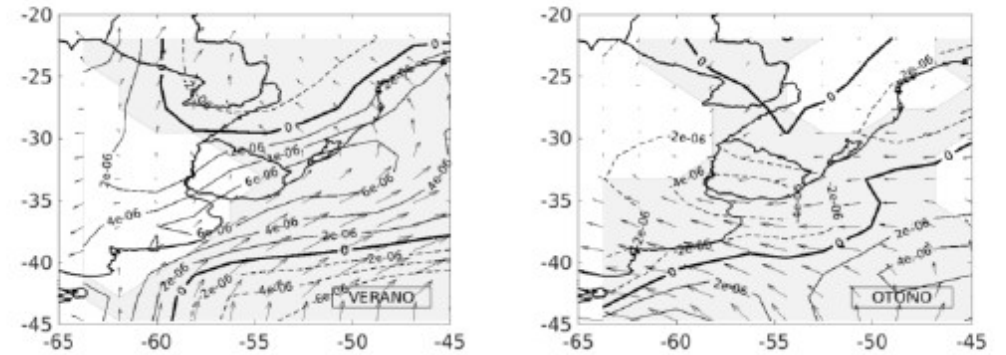


(c) invierno

(d) primavera

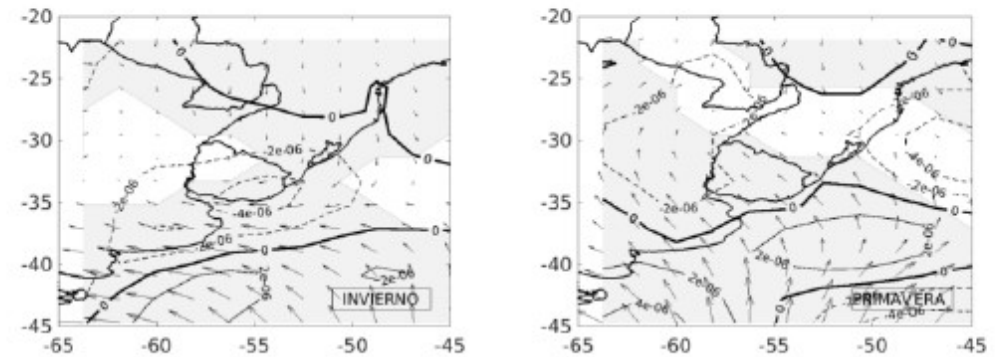


Vientos en superficie y su divergencia



(a) verano

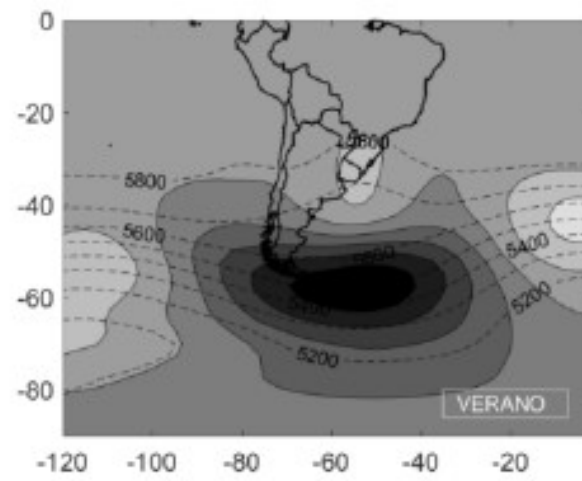
(b) otoño



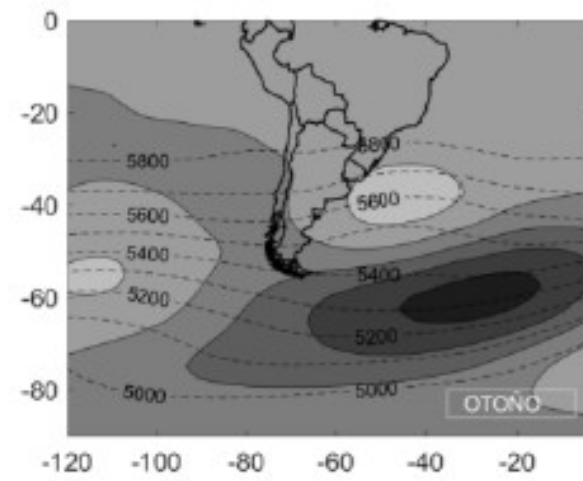
(c) invierno

(d) primavera

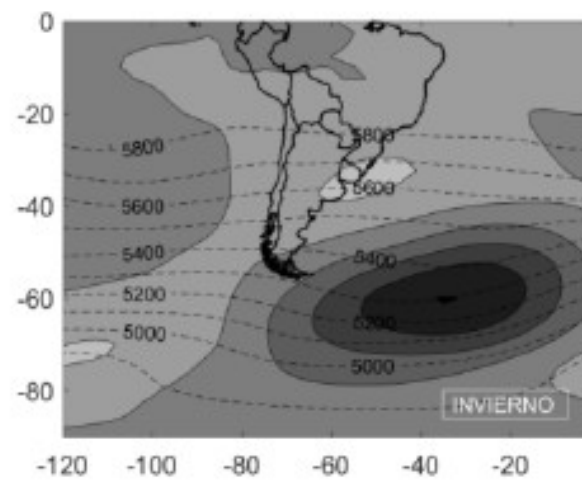




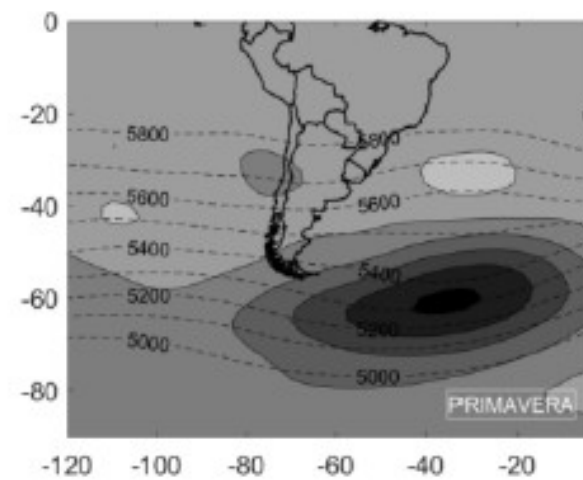
(a) verano



(b) otoño



(c) invierno



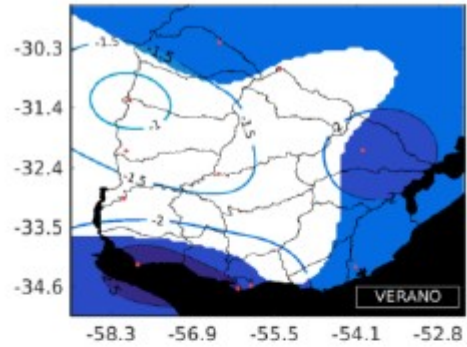
(d) primavera



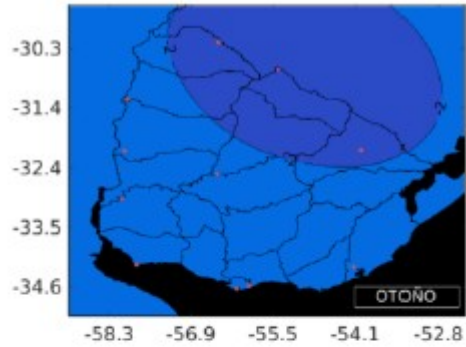
Figura 7: Idem Figura 2 para bloqueos en la región ATS.

TMAX

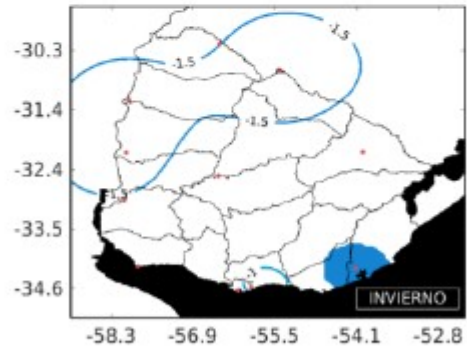
TMIN



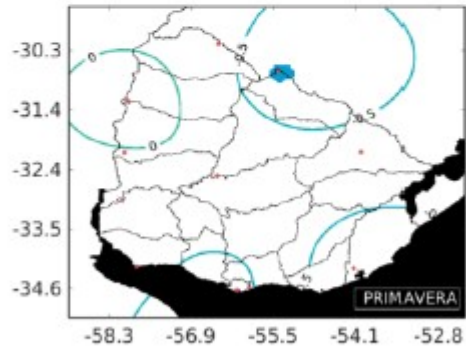
(a) verano



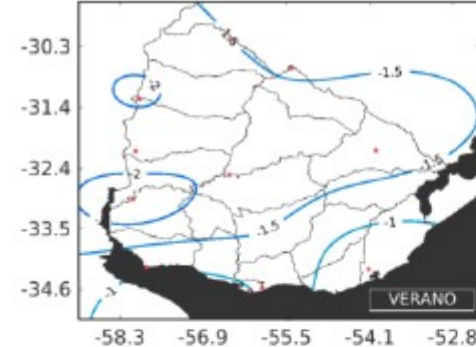
(b) otoño



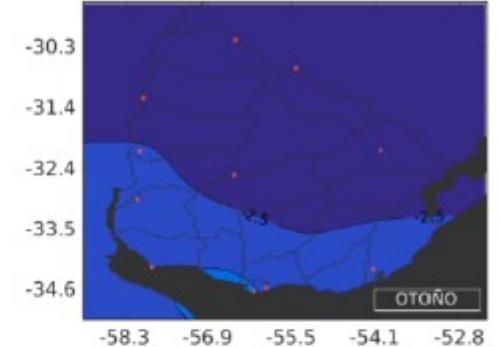
(c) invierno



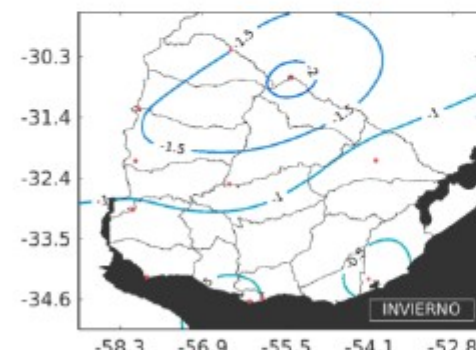
(d) primavera



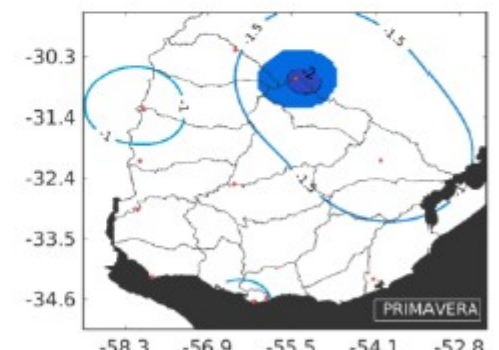
(a) verano



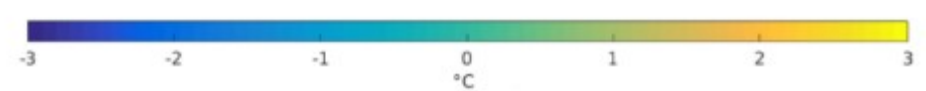
(b) otoño



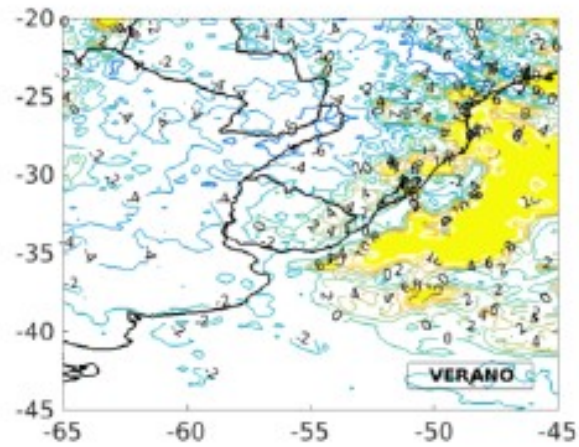
(c) invierno



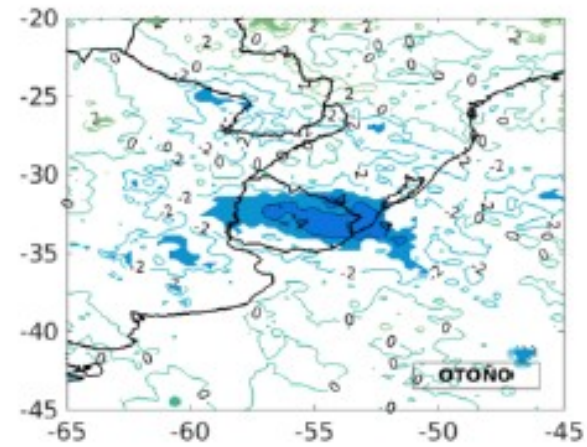
(d) primavera



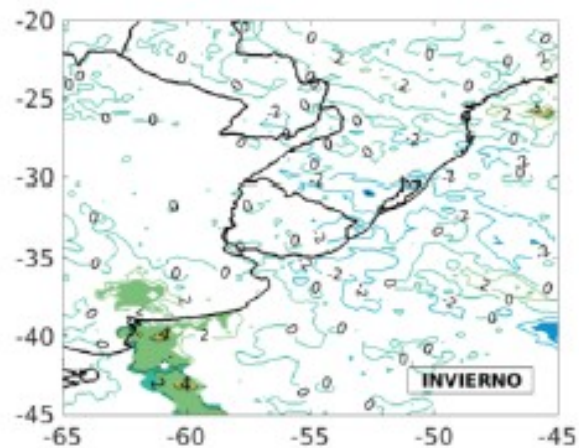
Lluvias



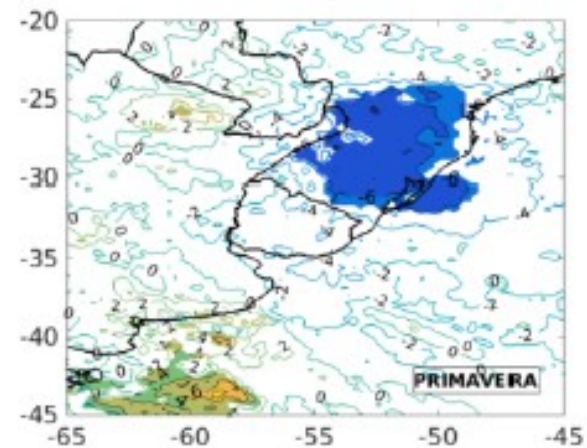
(a) verano



(b) otoño



(c) invierno



(d) primavera



NOAA Climate Prediction Center

Monitoreo de bloqueos en el HS

http://www.cpc.ncep.noaa.gov/products/precip/CWlink/blocking/real_time_sh/real_time_index_nrm.shtml

Mecanismos de formación de bloqueos

- Bloqueos son considerados como parte de una onda planetaria estacionaria y se estudia la interacción de estas ondas con procesos de mayor y menor frecuencia.

Rex 1950

EM TRABALHOS pioneiros sobre bloqueios, Rex (1950a, 1950b) sugeriu que a interação entre transientes de escala sinótica pode ser um mecanismo importante para a formação desses fenômenos. A grande

Charney de Vore (1979)

PARA Charney e De Vore (1979), as anomalias altamente persistentes na circulação atmosférica estariam associadas à ocorrência de múltiplos estados de equilíbrio para uma dada forçante externa. Eles encontraram mais de um estado de equilíbrio estável para padrões de escoamento forçados por topografia e assimetrias de temperatura. Alguns estados de equilíbrio apresentaram configuração com acentuada componente de onda (baixo índice zonal) e ressonantes, análogo a um padrão de bloqueio. Os autores sugeriram que a transição entre os distintos estados de equilíbrio (como, por exemplo, de um estado de equilíbrio de alto índice zonal para um com baixo índice zonal, representando o estabelecimento de um bloqueio) ocorreria por interações não lineares com perturbações de escalas menores em relação às quais esses estados estariam baroclinicamente instáveis. Por esse motivo, eles se referiram a tais estados de equilíbrio como “metaestáveis”. A instabilidade associada às perturbações de escalas menores agiria como uma forçante adicional que permitiria ao escoamento migrar de um estado de equilíbrio para outro.

Ec. de conservación de vorticidad potencial.

$$\left(\frac{\partial}{\partial t} + u \frac{\partial}{\partial x} + v \frac{\partial}{\partial y} \right) \frac{\zeta + f_0 + \beta y}{1 + (\eta - h)/H} \approx \frac{\partial}{\partial t} \times \left(\nabla^2 \psi - \frac{\psi}{\lambda^2} \right) + J \left(\psi, \nabla^2 \psi - \frac{\psi}{\lambda^2} + f_0 \frac{h}{H} + \beta y \right) = -f_0 \frac{D_E}{2H} \nabla^2 (\psi - \psi^*), \quad (1)$$

$$\left. \begin{aligned} (\psi, \psi^*) &= L^2 f_0 \sum_{i=1}^{\infty} (\psi_i, \psi_i^*) F_i, \\ h &= H \sum_{i=1}^{\infty} h_i F_i, \end{aligned} \right\}$$

$$\left. \begin{aligned} F_1 = F_A &= \sqrt{2} \cos \frac{y}{L}, & F_2 = F_K &= 2 \cos \frac{nx}{L} \sin \frac{y}{L} \\ F_3 = F_L &= 2 \sin \frac{nx}{L} \sin \frac{y}{L}, & F_4 = F_C &= \sqrt{2} \cos \frac{2y}{L} \\ F_5 = F_M &= 2 \cos \frac{nx}{L} \sin \frac{2y}{L}, & F_6 = F_N &= 2 \sin \frac{nx}{L} \sin \frac{2y}{L} \end{aligned} \right\},$$

$$\psi = \sum_{i=1}^6 \psi_i F_i = \psi_A F_A + \psi_K F_K + \psi_L F_L + \psi_C F_C + \psi_M F_M + \psi_N F_N,$$

$$\dot{\psi}_A = -k_{01}(\psi_A - \psi_A^*) + h_{01}\psi_L, \quad (11)$$

$$\dot{\psi}_K = -(\alpha_{n1}\psi_A - \beta_{n1})\psi_L - \delta_{n1}\psi_C\psi_N - k_{n1}(\psi_K - \psi_K^*), \quad (12)$$

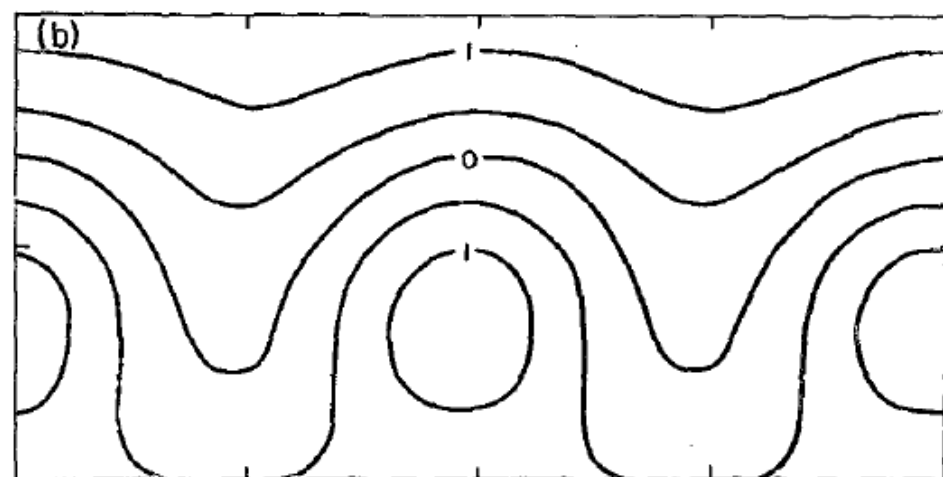
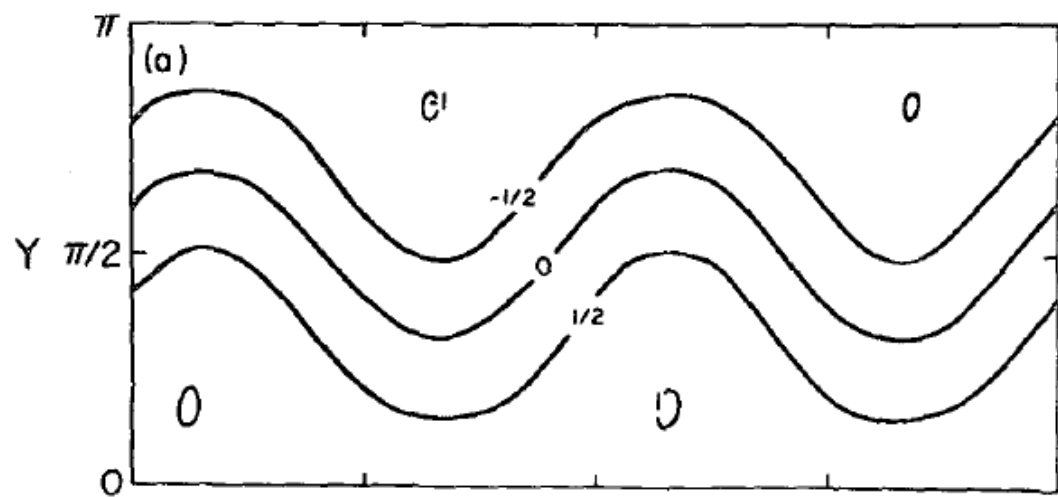
$$\dot{\psi}_L = (\alpha_{n1}\psi_A - \beta_{n1})\psi_K + \delta_{n1}\psi_C\psi_M - k_{n1}(\psi_L - \psi_L^*) - h_{n1}\psi_A, \quad (13)$$

$$\dot{\psi}_C = \epsilon_n(\psi_K\psi_N - \psi_L\psi_M) - k_{02}(\psi_C - \psi_C^*) + h_{02}\psi_N, \quad (14)$$

$$\dot{\psi}_M = -(\alpha_{n2}\psi_A - \beta_{n2})\psi_N - \delta_{n2}\psi_C\psi_L - k_{n2}(\psi_M - \psi_M^*), \quad (15)$$

$$\dot{\psi}_N = (\alpha_{n2}\psi_A - \beta_{n2})\psi_M + \delta_{n2}\psi_C\psi_K - k_{n2}(\psi_N - \psi_N^*) + h_{n2}\psi_C, \quad (16)$$

Sistema de ecuaciones no-lineal en las amplitudes de las ondas (“modos”)



Nakamura y Wallace 1993

manutenção dos bloqueios. Nakamura e Wallace (1993) indicaram que a amplificação de alguns anticiclones de bloqueios se segue a uma atividade anormalmente alta de perturbações migratórias de alta frequência, associadas à ciclogênese explosiva. Tsou e Smith (1990) discutiram a interação entre uma crista de bloqueio em amplificação e as perturbações migratórias, e concluíram que os transientes exercem uma realimentação positiva que age para reforçar a crista de bloqueio.



Atmospheric blocking as a traffic jam in the jet stream

NOBORU NAKAMURA AND CLARE S. Y. HUANG [Authors Info & Affiliations](#)

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↓ 3,982 ” 83



Abstract

Atmospheric blocking due to anomalous, persistent meandering of the jet stream often causes weather extremes in the mid-latitudes. Despite the ubiquity of blocking, the onset mechanism is not well understood. Here we demonstrate a close analogy between blocking and traffic congestion on a highway by using meteorological data and show that blocking and traffic congestion can be described by a common mathematical theory. The theory predicts that the jet stream has a capacity for the flux of wave activity (a measure of meandering), just as the highway has traffic capacity, and when the capacity is exceeded, blocking manifests as congestion. Stationary waves modulate the jet stream's capacity for transient waves and localize block formation. Climate change likely affects blocking frequency by modifying the jet stream's proximity to capacity.



Wave Breaking Events and Their Link to Rossby Wave Packets and Atmospheric Blockings During Southern Hemisphere Summer

Iago Pérez-Fernández, Marcelo Barreiro, Noémie Ehstand, Emilio Hernández-García  Cristobal López

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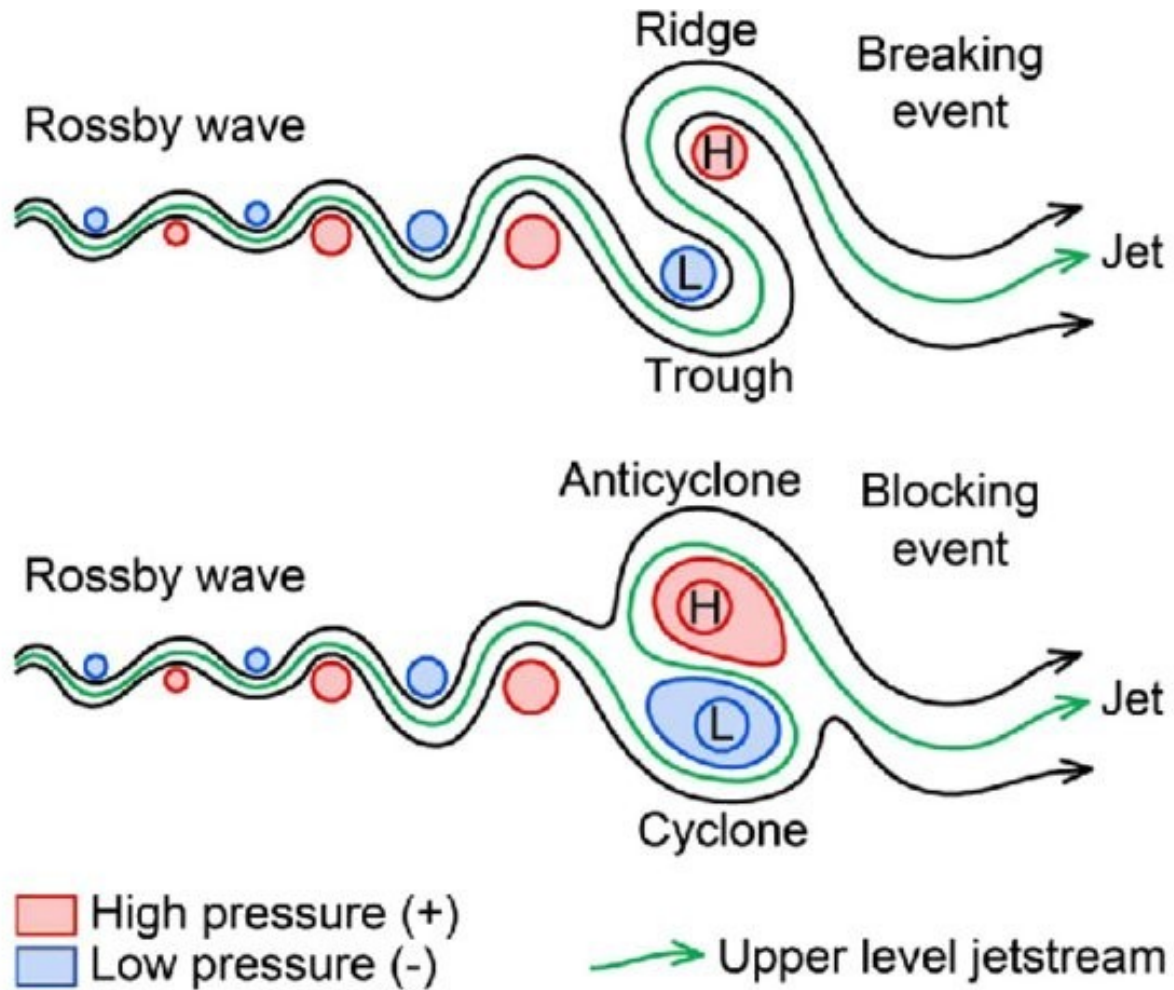
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Abstract

Rossby Wave Packets (RWP) are atmospheric perturbations located at upper levels in mid-latitudes which, in certain cases, terminate in Rossby Wave Breaking (RWB) events. When sufficiently persistent and spatially extended, these RWB events are synoptically identical to atmospheric blockings, which are linked to heatwaves and droughts. Thus, studying RWB events after RWP propagation and their link with blocking is key to enhance extreme weather events detection 10–30 days in advance. Hence, here we assess (a) the occurrence of RWB events after the propagation of transient RWP, (b) whether long-lived RWP (RWP with a lifespan above 8 days, or LLRWP) are linked to large-scale RWB events that could form a blocking event, and (c) the proportion of blocking situations that occur near RWB events. To do so, we applied a tracking algorithm to detect transient RWP in the southern hemisphere during summertime between 1979 and 2021, developed a wave breaking algorithm to identify RWB events, and searched for blocking events with different intensities. Results show that LLRWP and the other RWP displayed large-scale RWB events around 40% of the time, and most RWB events in both distributions last around 1–2 days, which is not long enough to identify them as blocking situations. Nearly 17% of blockings have a RWB event nearby, but barely 5% of blockings are linked to RWP, suggesting that transient RWP are not strongly linked to blocking development. Lastly, large-scale RWB events associated with RWP that lasted less than 8 days are influenced by El Niño–Southern Oscillation.

Rompimiento de onda → bloqueo



Ondas de Rossby cuasi-estacionarias – rol de los trópicos

UMA outra linha de pesquisa aborda o aspecto da formação dos bloqueios procurando evidências de que também os mecanismos de baixa frequência na atmosfera desempenham um papel importante.

En particular, se propone el rol de fuentes de calor en los trópicos que generan ondas de Rossby extratropicales persistentes.