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Austral teleconnection patterns associated to generalized frosts over Southern South America

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Austral teleconnection patterns associated to generalized frosts over Southern South America

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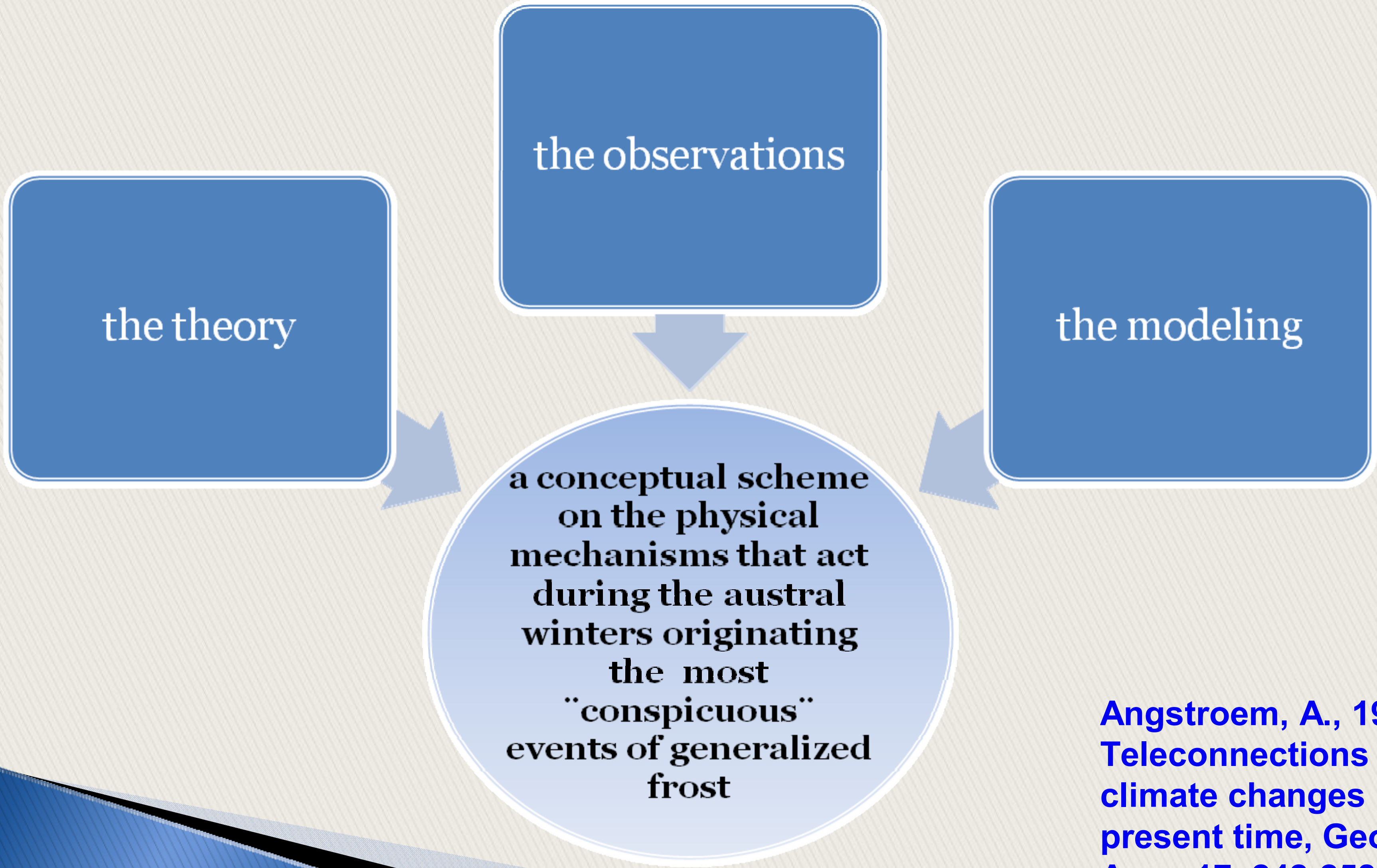
ICTP Trieste – Italy, 17-20 Nov. 2008

This work is a clear example of how the teleconnection "theory" can be used to explain an important meteorological event being also a good example of how theory, observations and modeling are linked.



Angstroem, A., 1935: Teleconnections of climate changes in present time, Geogr. Ann., 17, 242-258.

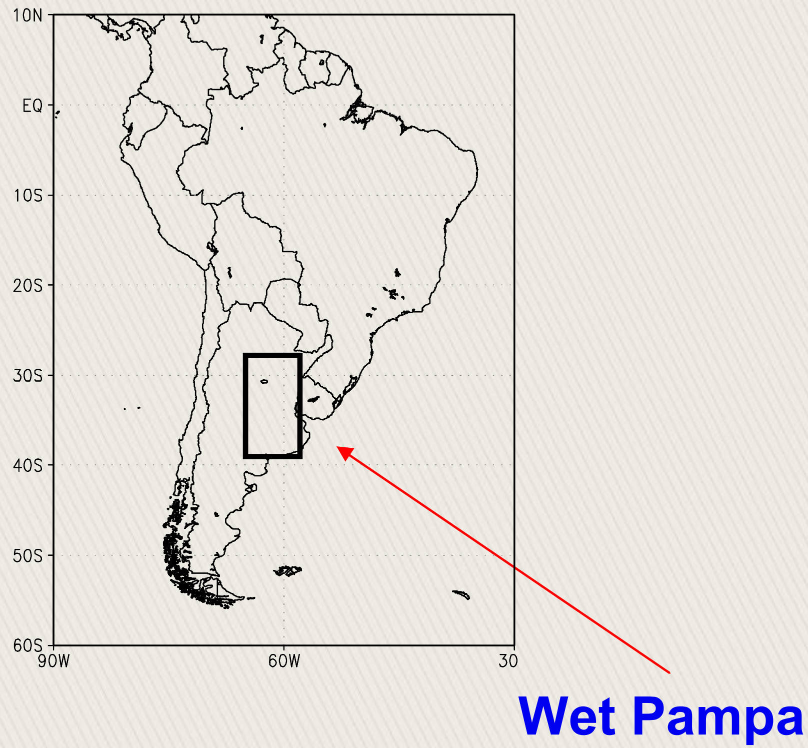
OBJECTIVE

To analyze the role played by the propagation of remotely-generated Rossby waves during SH winter, in the development of frost events in southern South America

APPROACH

- **A criterion of spatial extension is established in order to identify the frost events**

- **The frost events take place in Wet Pampa –central-eastern Argentina- the most important agricultural region of the country**



SPATIAL EXTENSION CRITERION FOR FROST EVENTS

Why the spatial extension?

- **Identifies regional scale frosts and excludes those exclusively local**
- **Allows the study of associated larger scale conditions**

For each day: $$\frac{\text{Number of stations with frost}}{\text{Total number of stations with data that day}}$$

Each day is classified as
- **Isolated frost**
- **Partial frost**
- **Generalized frost**

GENERALIZED FROST: there must be at least 75% of stations with frost

Müller et al. (2000) *Intern. Jour. of Climatol.*

CRITERION OF EXTREME FREQUENCY OF FROST OCCURRENCE

Why extreme frequency of occurrence?

- **Generalized frosts display large seasonal and interannual variability in the frequency of occurrence**

Therefore:

We identify the winters (JJA) with a number of generalized frosts that is:

- **greater than the 1961-90 average +1 σ,** ***identified as*** **GF +σ**
- **smaller than the 1961-90 average -1 σ,** ***identified as*** **GF -σ**

GF +σ winters: 1970, 1976, 1988

GF -σ winters: 1968, 1973, 1982, 1986

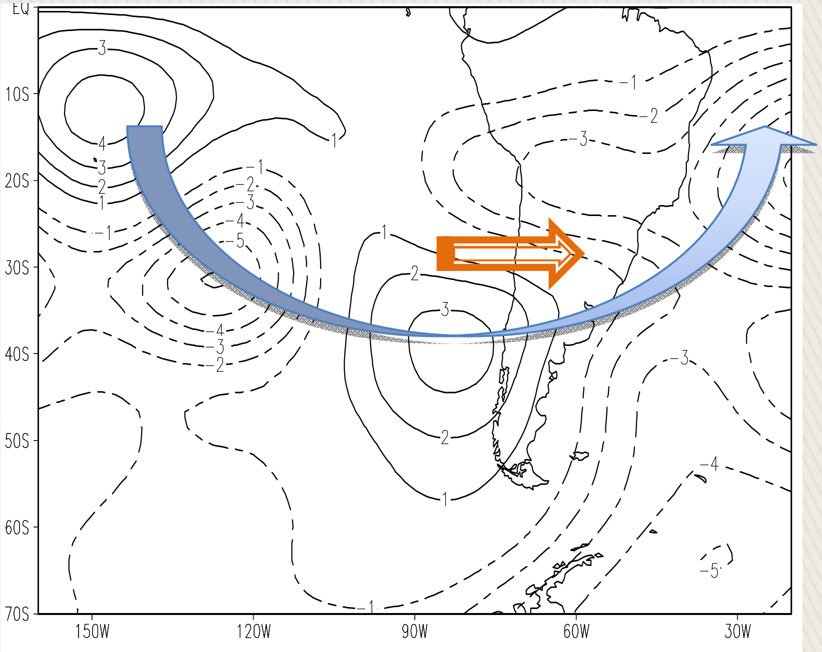
Müller et al. (2005) *Theor. and Applied Climatol.*

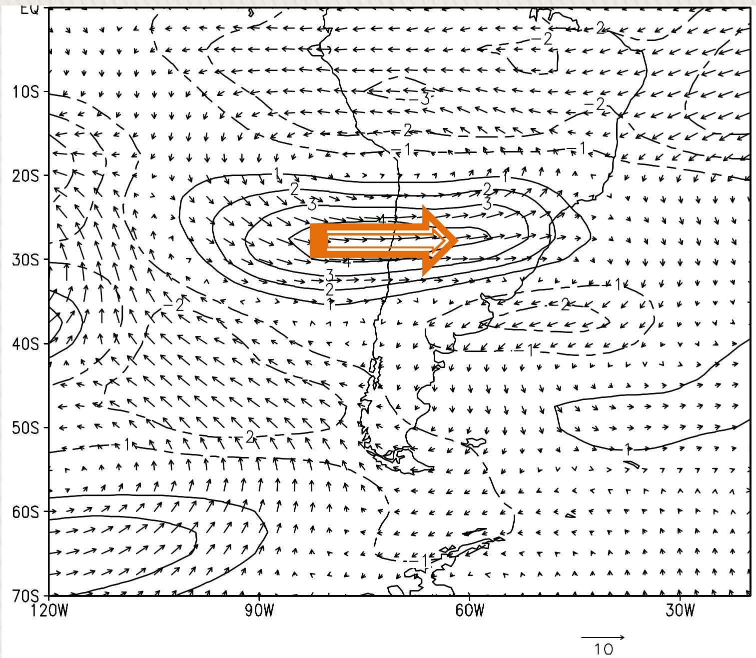
+ σ GENERALIZED FROST COMPOSITES

stream function anomalies
($x\ 10^{-6}\ m^2s^{-1}$)

250 hPa

vector wind vector and zonal component anomalies (ms^{-1})





❖**It is interesting to notice that these fields are not observed in the composites of other frost groups: (isolated and partial)**

observations

Müller et al. (2005) *Theor. and Applied Climatol.*
Müller (2007) *Intern. Jour. of Climatol.*

HIPOTHESIS

The extreme occurrence of frost events are conditioned by large scale patterns of Rossby wave propagation, which are trigged remotely

METHODOLOGY

- Numerical Simulations using a 12 sigma levels Global Baroclinic model (IGCM), T42
- Thermal forcing is placed where tropical convection anomalies are observed

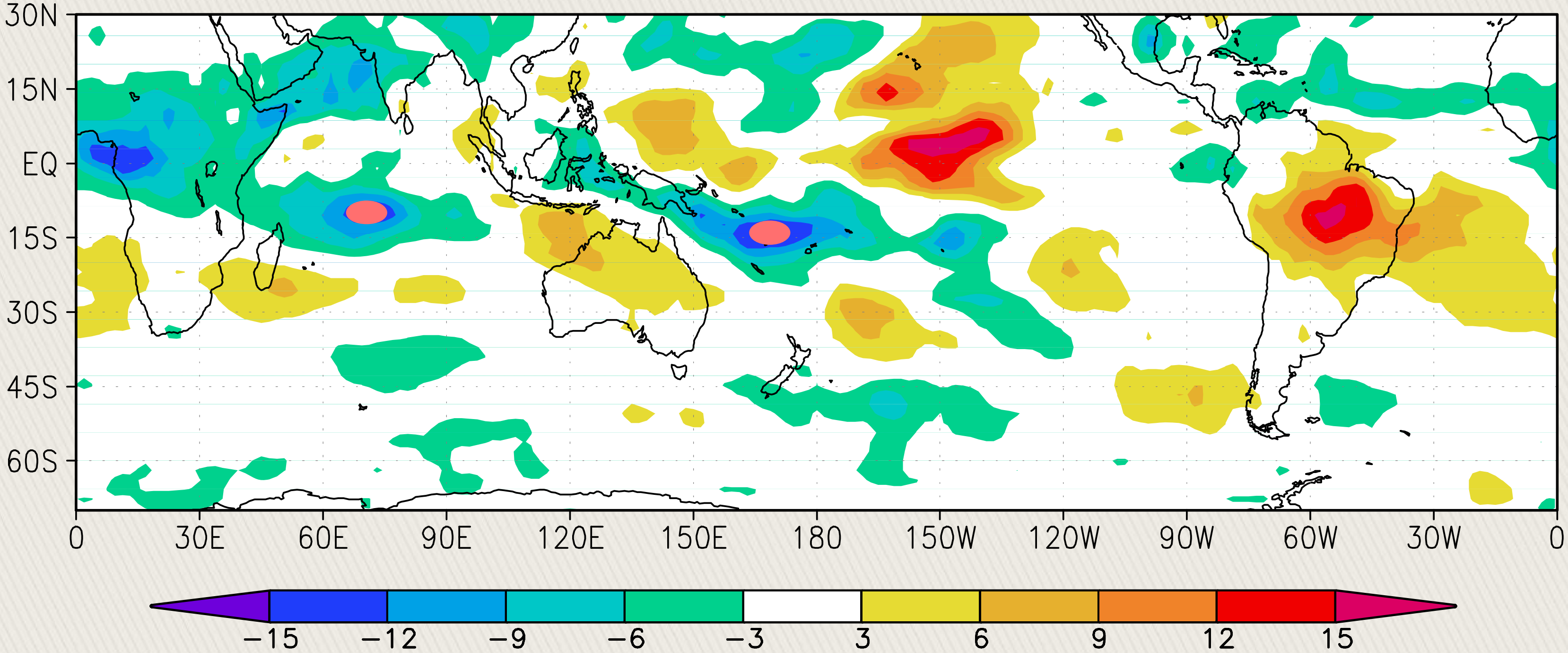
Basic State: GF +σ winter *(henceforth* GF +σ*)*

DATA: NCEP/NCAR Reanalysis

Additional simulation with other basic state → GF -σ winter *(henceforth* GF -σ*)*

+ σ GENERALIZED FROST COMPOSITES

Observed OLR Anomaly (Wm-2)



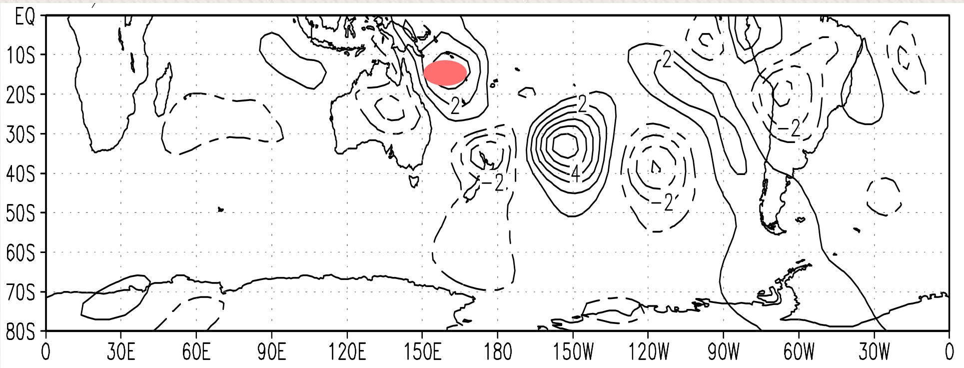
Statistically significant anomalies

observations

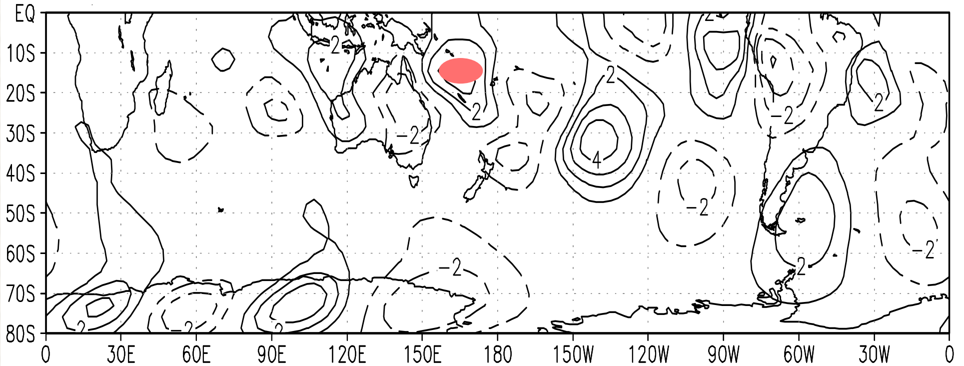
Müller et al. (2008) *Annales Geophysicae*

BAROCLINIC MODEL SIMULATIONS FOR THE TROPICAL FORCING

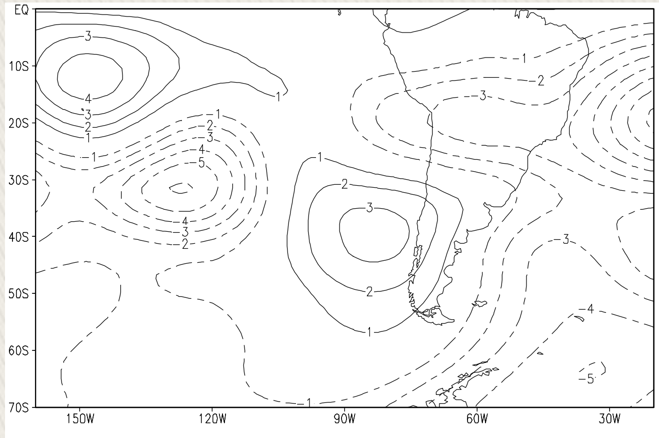
250 hPa meridional wind anomalies (ms^{-1})
Day 10 of simulation



GF +σ



GF -σ

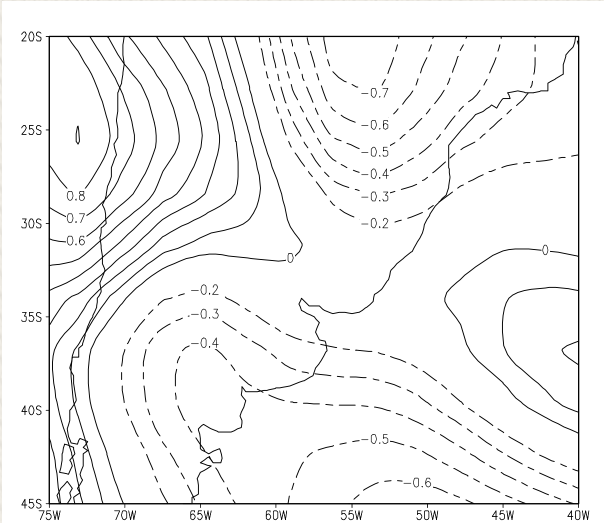


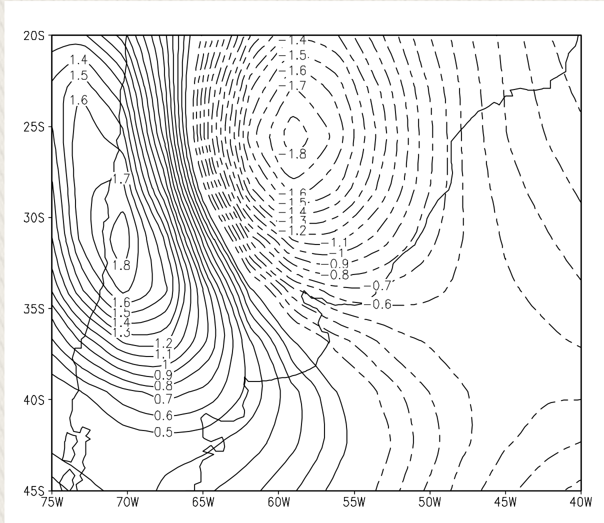
stream function anomalies
(x 10^{-6} m^2s^{-1})

modeling

Müller et al. (2008) *Annales Geophysicae*

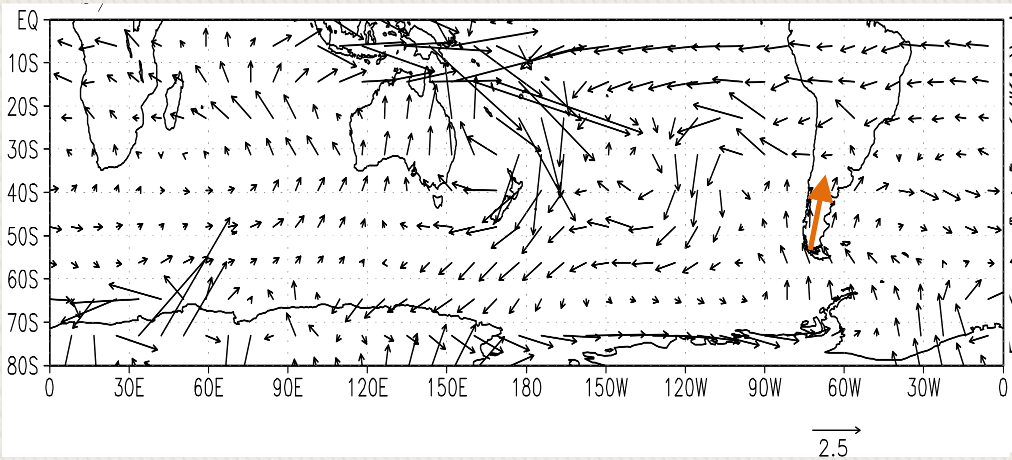
GF +σ surface temperature anomalies (°C) **GF -σ**

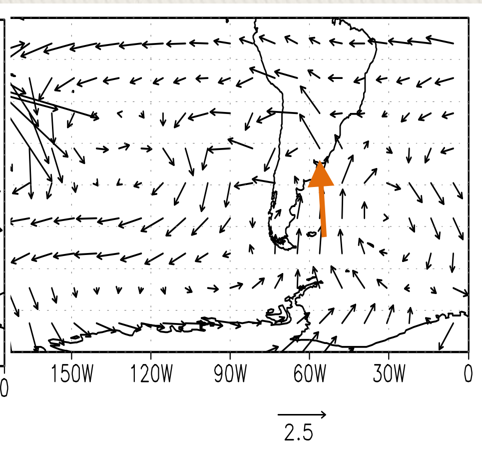




850 hPa wind vector anomalies

GF +σ





GF -σ

DRY and cold air advection **WET and cold air advection**

modeling

Müller et al. (2008) *Annales Geophysicae*

HOW ARE THE OBSERVED WAVE PROPAGATION PATTERNS ASSOCIATED WITH THE GF?

DATA: **NCEP/NCAR Reanalysis and Argentinean Meteorological stations**

METHODOLOGY:

- **Composite analysis – 14 events during GF +σ**

SELECTION OF THE GF DAYS

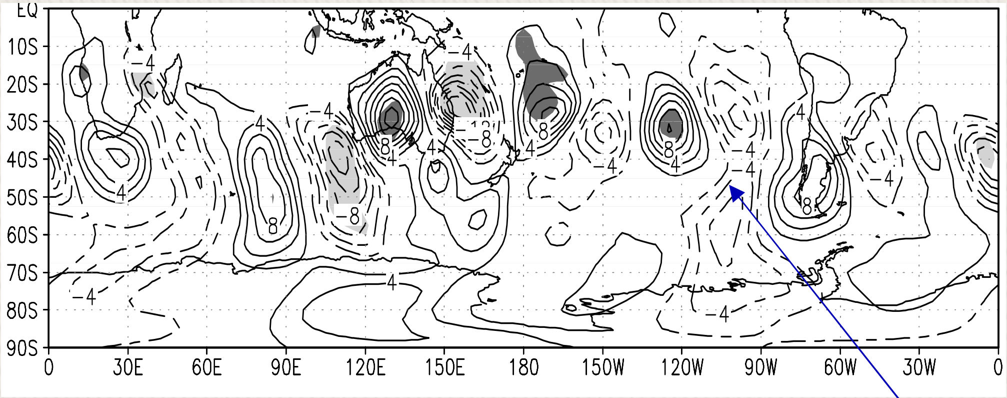
- **Two consecutive episodes must be separated by seven days**
- **The selected episodes cannot be associated with the same synoptic system**

Müller et al. (2005) *Theor. and Applied Climatol.*

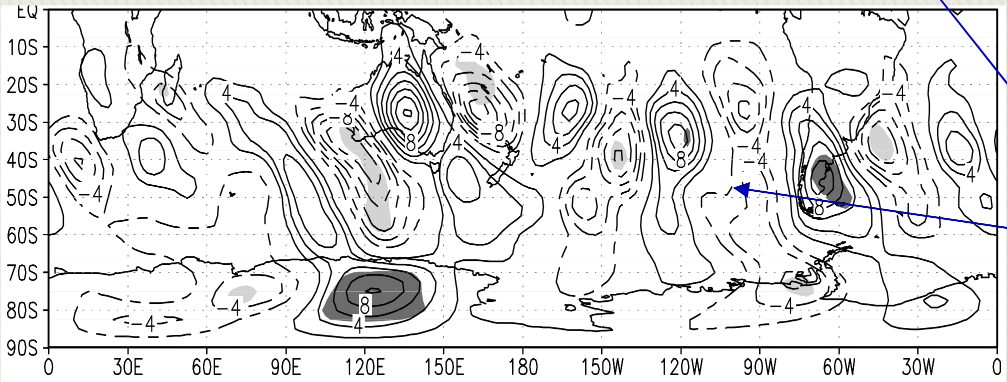
Observed 250 hPa meridional wind anomalies (ms^{-1})

GF +σ

2 days before



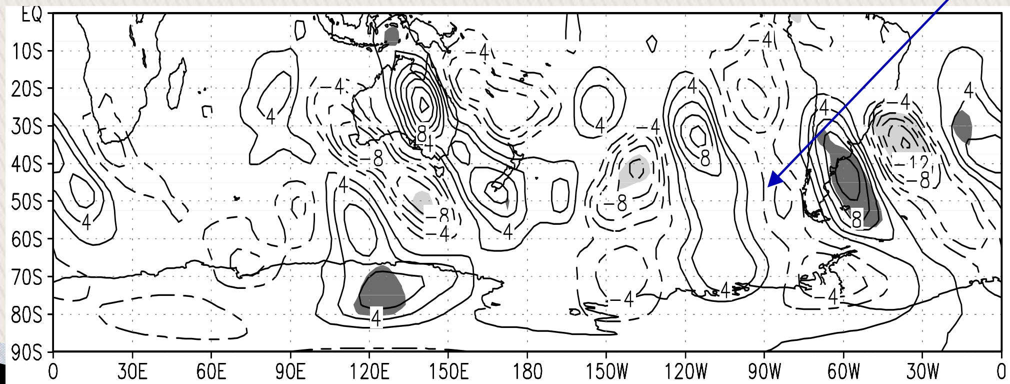
1 day before



PHASE

COINCIDENCE

The event day



observations

Müller et al. (2005) *Theor. and Applied Climatol.*

In the various numerical experiments of GF +σ associating the observed convection with the propagations pattern it was not obtained this double wave train with the peculiarity of coincidence phases …

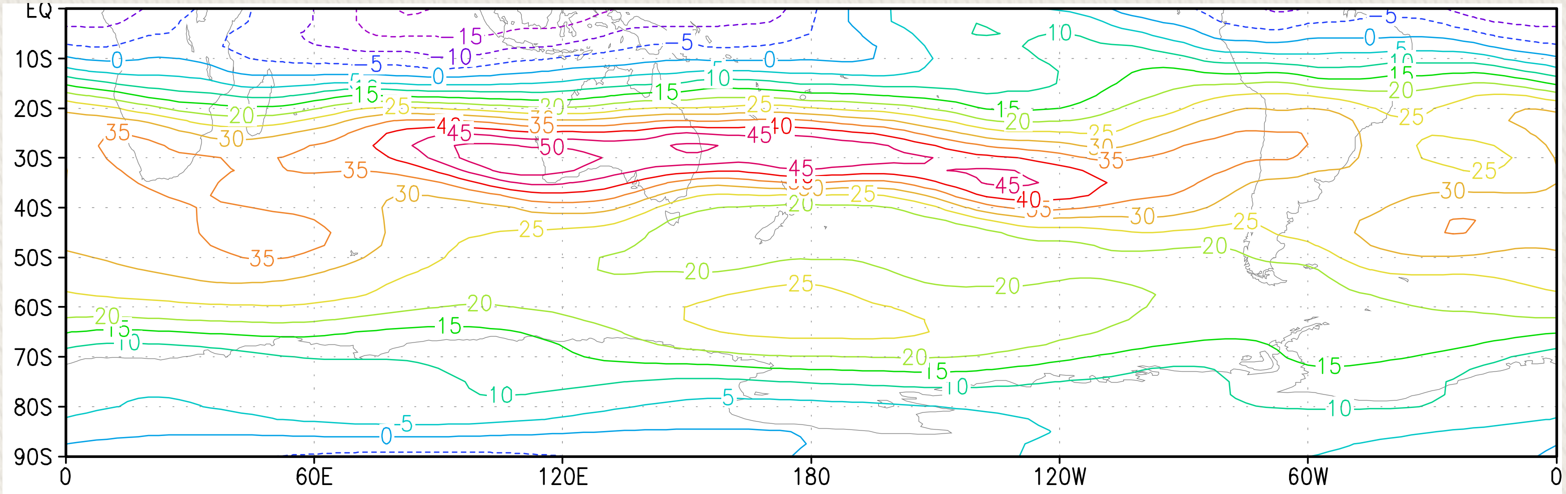
Under which circumstances the atmosphere creates conditions that would generate a propagations pattern as the observed one?

Thus we studied the characteristics of the GF +σ (and GF -σ) basic state from the Rossby wave linear theory point of view

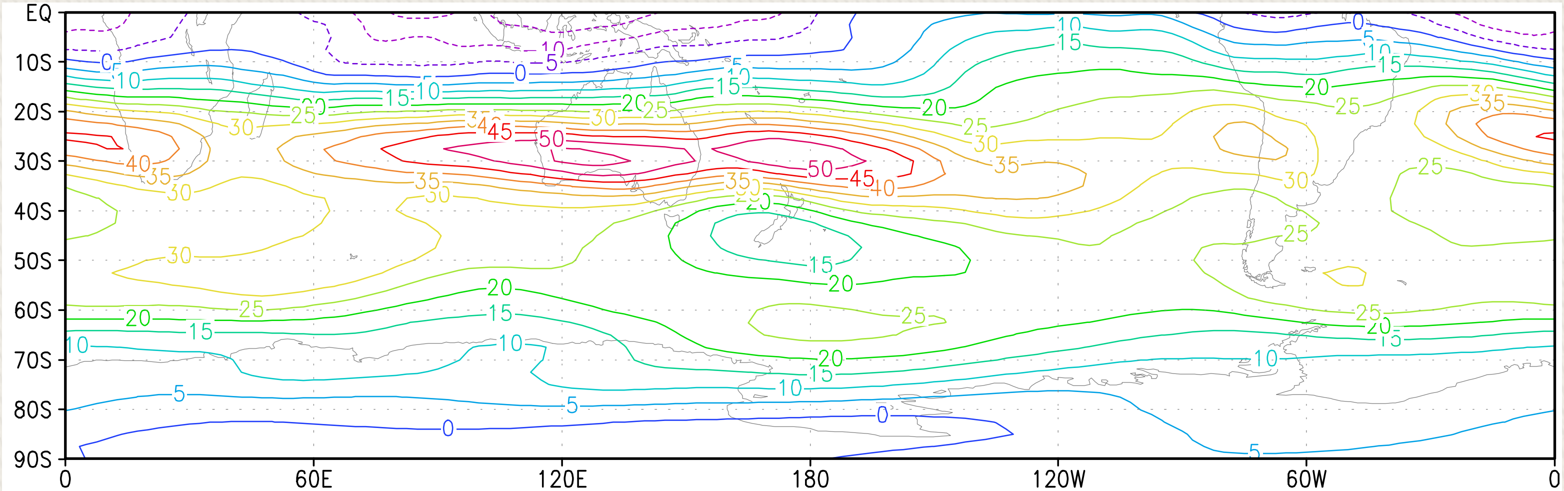
DISTRIBUTION OF THE ROSSBY STATIONARY WAVENUMBER

Calculate Ks number: $K_s = \left(\frac{\beta_*}{\overline{U}}\right)^{1/2}$ $\beta_* = \beta - \frac{\partial^2 \overline{U}}{\partial y^2}$

zonal wind component (ms^{-1}) at 250 hPa



GF +σ

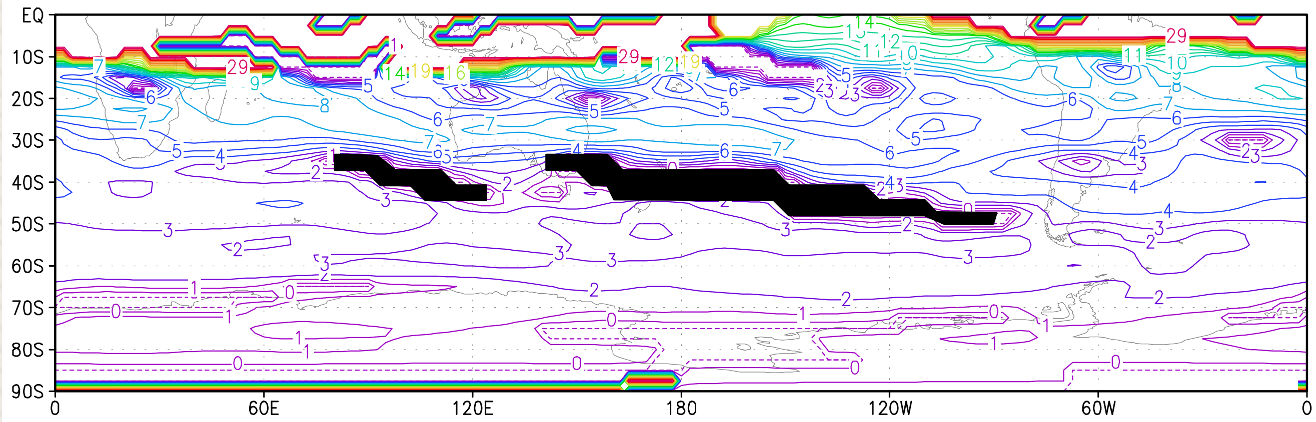


GF -σ

theory
observations

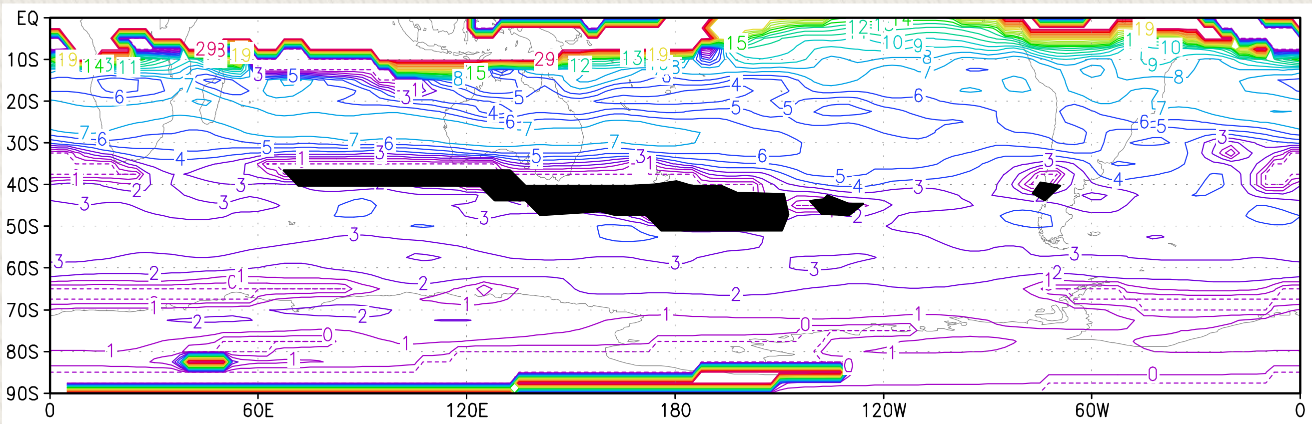
Müller and Ambrizzi (2007) *Climate Dynamics*

Ks number at 250 hPa



GF +σ

In black shading is the inhibiting region of wave propagation, K_s=0



GF -σ

The distribution of Ks emphasizes the important of the jets as efficient wave guides and to identify the regions where the Rossby wave propagation is not allowed.

theory
observations

Müller and Ambrizzi (2007) *Climate Dynamics*

Therefore, the previous hypothesis is enlarged:

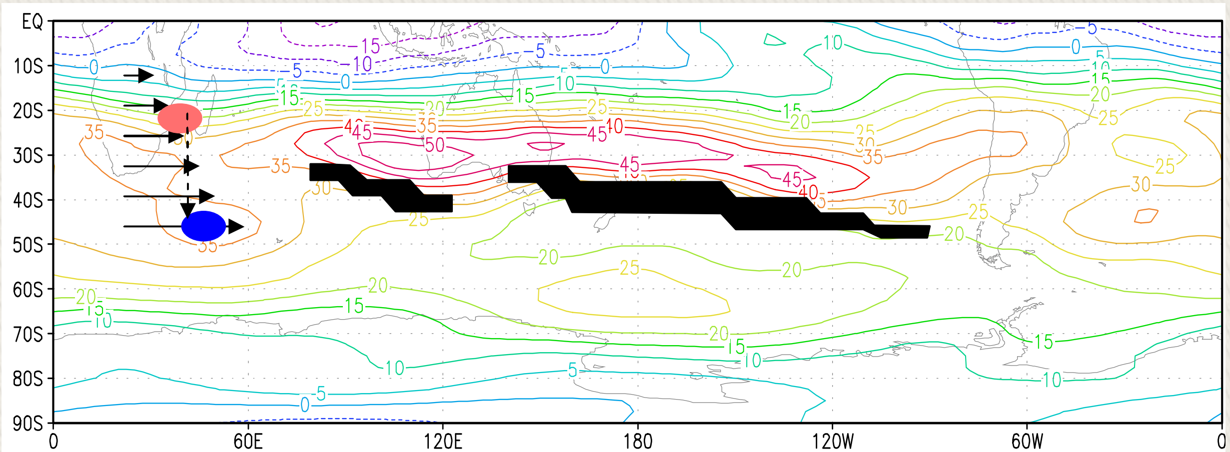
The Rossby wave which are trigged remotely, propagates along the subtropical and polar waveguides and their phases coincide before entering the SA continent in GF +σ

What is the origin of these propagation wave patterns?

METHODOLOGY

- Numerical simulations using a 12 sigma levels IGCM
- Thermal forcing is placed where the conditions are favorable for Rossby wave propagations according to Ks of GF +σ:

in black (K_s=0)

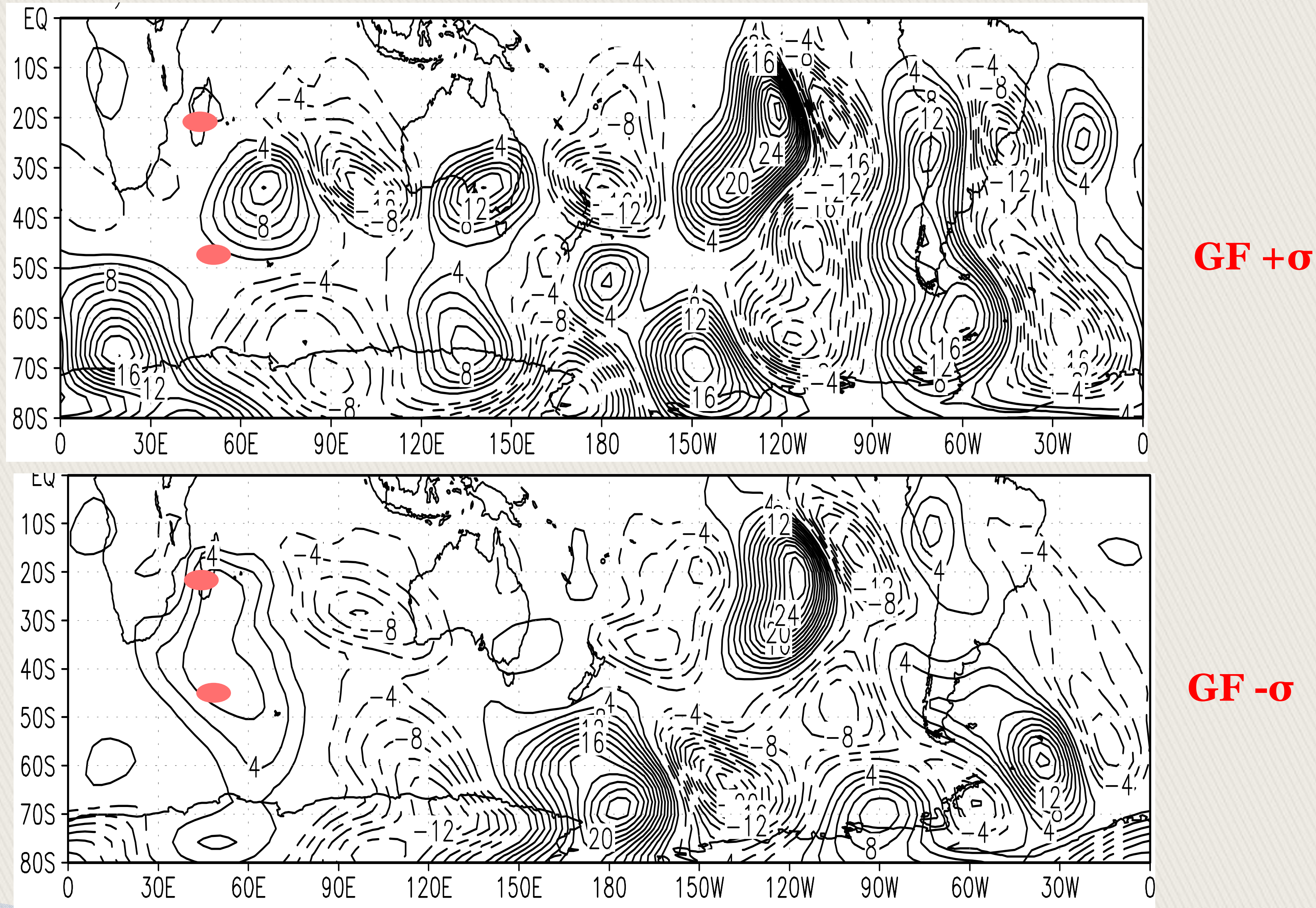


40ºE-20ºS is the location of the subtropical jet entrance

45ºE-40ºS is the location upstream the zero zonal wavenumber (K_s=0)

theory
observations

simulated 250 hPa meridional wind anomalies (ms^{-1})
Day 14 of integration

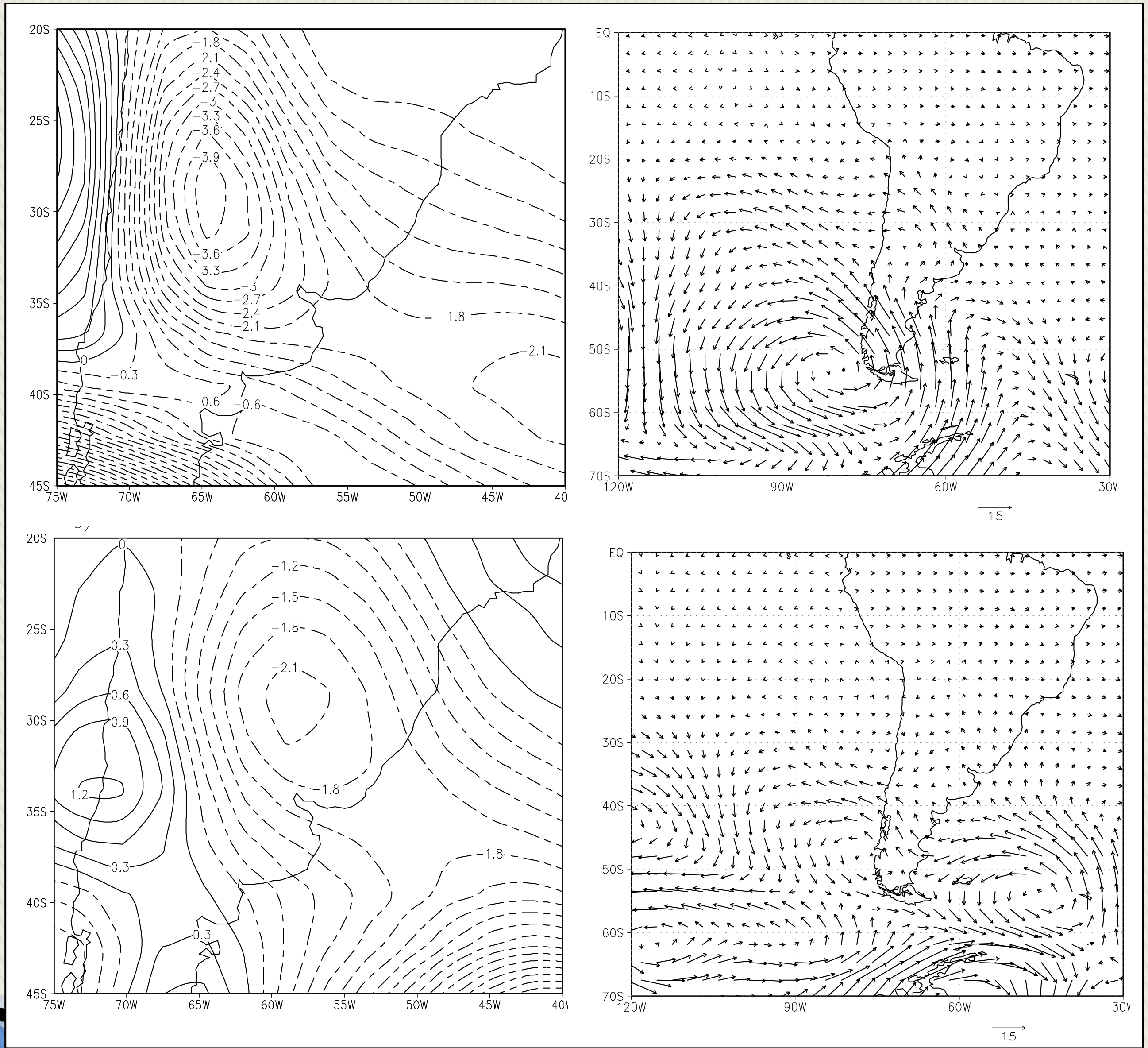


modeling

Müller and Ambrizzi (2007) *Climate Dynamics*

surface temperature anomalies (°C)

850 hPa wind vector anomalies



GF +σ

GF -σ

modeling

Müller and Ambrizzi (2007) *Climate Dynamics*

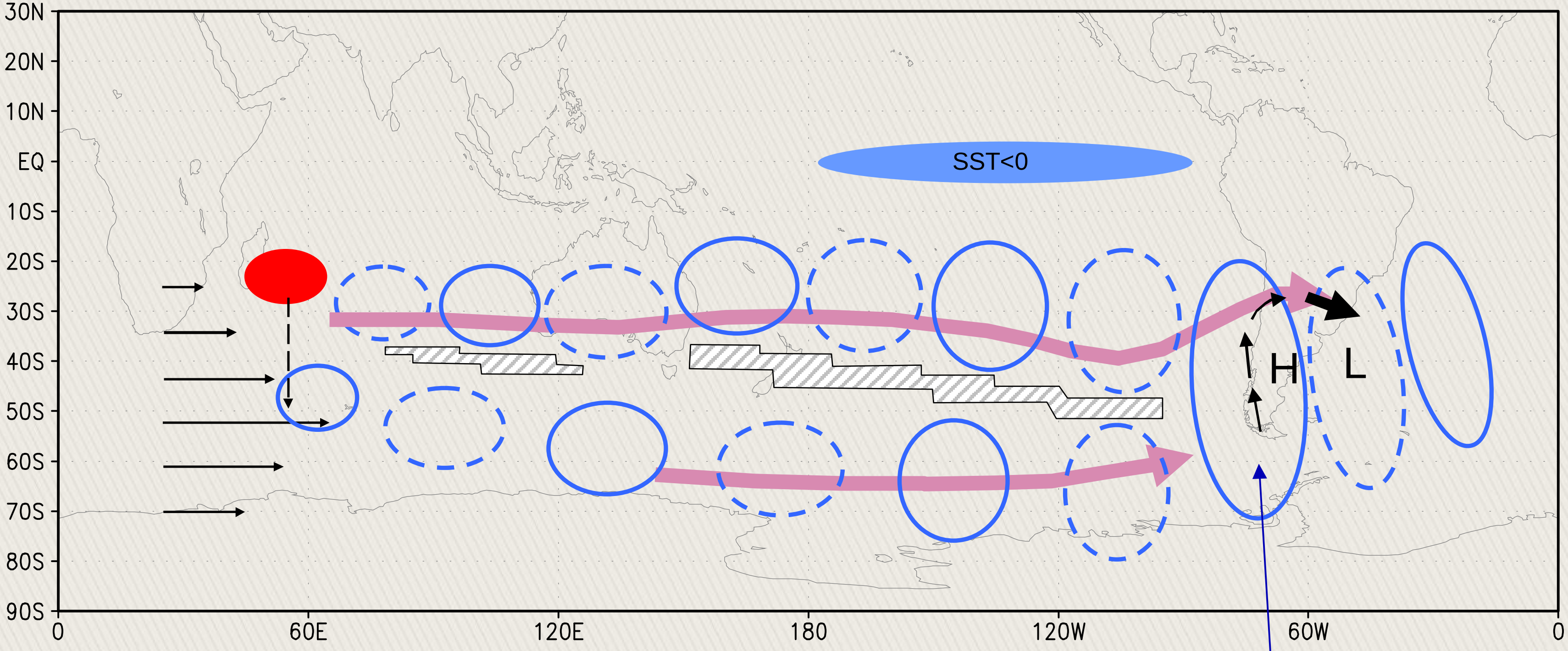
As it was mentioned …

a conceptual scheme on the physical mechanisms that act during the austral winters originating the most ¨conspicuous¨ events of generalized frost

"conspicuous" events are the more frequent and/or persistent generalized frost

THE PHYSICAL MECHANISM THAT FAVOUR HIGH FREQUENCY OCCURRENCE OF GF

Origin and evolution of the Rossby waves propagation patterns
in the GF +σ austral hemisphere



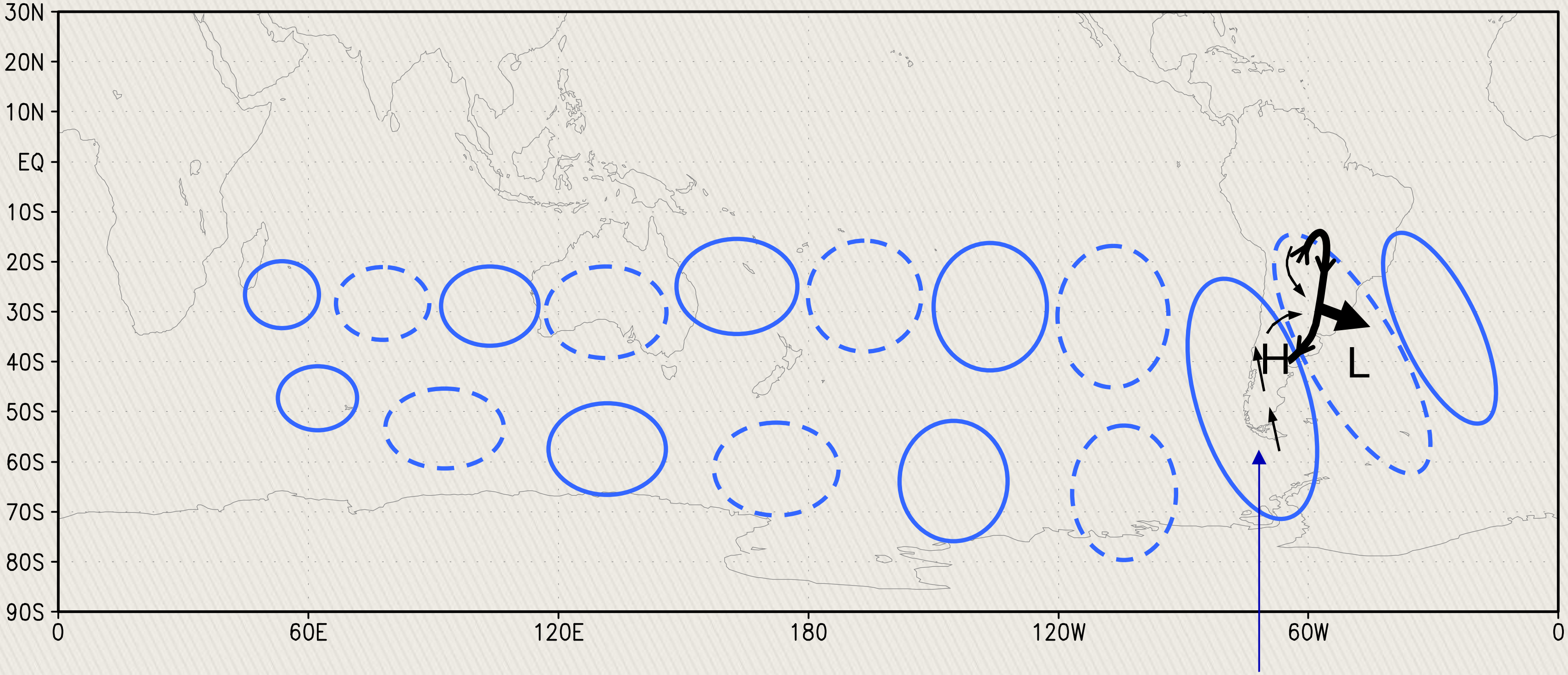
It emphasizes the phases coincidence

theory
modeling
observations

Müller and Ambrizzi (2007) *Climate Dynamics*

It is similar to the physical mechanism that generates a

MORE PERSISTENT GF EVENTS



It emphasizes the quasi-stationary

MORE PERSISTENT ➡ DOBLE WAVE TRAIN

modeling
observations

Müller and Berri (2007) *Mon. Wea. Rev.*

SUMMARY

✓ The observational evidence and the theoretical-observational analysis of the Southern Hemisphere teleconnection patterns associated to extreme cold events in the Wet Pampa were well simulated by a baroclinic model.

✓The main wave activity inside the subtropical and polar jets that guide the waves towards South America are dependent of the basic states and they are important in the determination of the final trajectory of the waves.

✓The two wave trains generated in the South Indian Ocean for GF +σ, propagate to the east independently of each other, and before reaching the South American continent they merge in an unique pattern creating the appropriate conditions for generalized frosts. There is no wave phase coincidence when the GF -σ basic state is used

✓The phase coincidence found in the wave propagation patterns is the dynamical condition that determines the greater frequency of occurrence of generalized frosts in the Wet Pampa during some specific winters. It maintains a polar air advection over the southern cone of South America, favoring the conditions for a surface temperature drop over a large region

CLIMATE STUDIES GROUP

THANK YOU FOR YOUR ATTENTION

THANKS TO ICTP FOR THE INVITATION AND, IN PARTICULAR, TO DR. I.-S. KANG