IMPACTS OF AUSTRAL WINTER HADLEY CIRCULATION CHANGES ON STATIONARY ROSSBY WAVES PROPAGATION

Ana C.V. Freitas, Tércio Ambrizzi and Jorgen Frederiksen

Institute of Astronomy, Geophysics and Atmospheric Sciences (IAG), São Paulo, Brazil

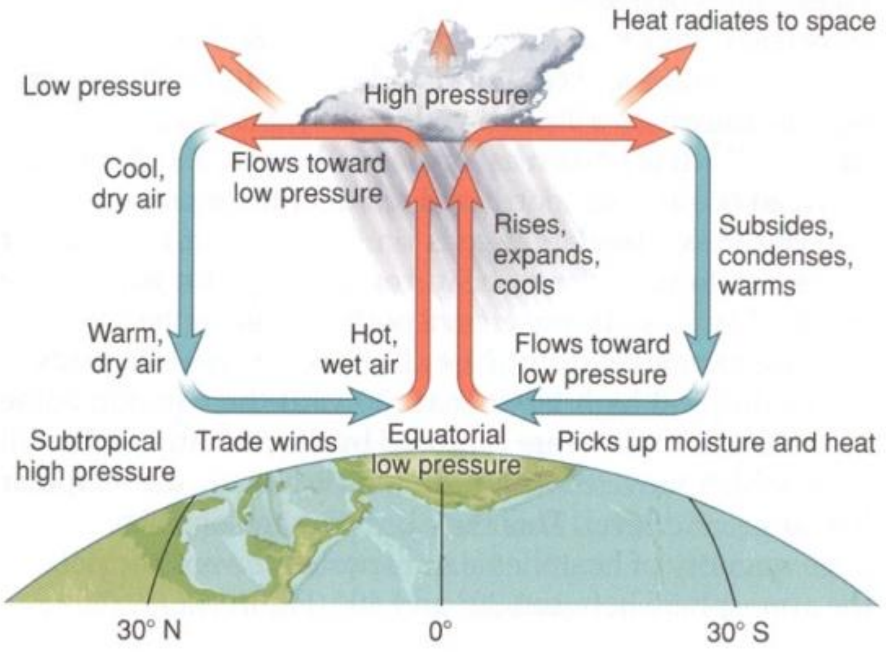
CSIRO Marine and Atmospheric Research (CMAR), Aspendale, Australia

WCRP Conference for Latin America and the Caribbean:
Developing, linking and applying climate knowledge

Hadley circulation (HC) and Rossby waves

CONNECTION

Deep convection in the rising branch and the associated divergence at high levels - Rossby wave is generated.



Tropical variability affects the extra-tropical atmospheric circulation

Wave trains propagation

- Marengo et al. (2002) – Rossby wave train emanating from the western tropical Pacific during wintertime can lead to cooling and occurrence of freezes in south-eastern South America.

- Müller and Ambrizzi (2007) - in the austral winter, two Rossby wave trains over South Pacific, with sources in the Western Pacific and south of Australia, favors high frequency occurrence of generalized frosts over the Wet Pampa in South America.

Climate change context

- **HC response to an increase in the anthropogenic greenhouse gas emissions: weakening and a poleward expansion of this circulation.**
- **Vecchi and Soden (2007) - anthropogenic weakening for the Walker circulation.**

↓

- **Haarsma and Selten (2012) - the weakening of the Walker circulation induces a significant *weakening of the upper tropospheric divergence in the NH* that changes the Rossby wave source and modify the generation of Rossby waves that propagate into the extra-tropics.**

Stationary Rossby Waves (SRW) Propagation

- **The impact of the changes in the tropical circulation on the extra-tropical planetary wave structure not only depends on the tropical forcing itself but also on the propagation characteristics of Rossby waves.**

Objectives

- Investigate how the changes in the intensity of the HC impact the SRW energy propagation in the SH extra-tropics for the period of 1979-2010.

- NCEP-DOE Reanalysis 2 dataset and the CSIRO Mk3L general circulation model [simulations with observed sea surface temperatures (SSTs) and time evolving historical carbon dioxide (CO2) concentrations] are employed.

Observational data

- **NCEP-DOE Reanalysis 2 - 2.5° latitude by 2.5° longitude grid (Kanamitsu et al., 2002).**
- **Hadley Centre Global Sea Ice and Sea Surface Temperature (HADISST) - 1°x1° grid (Rayner et al., 2003).**

Model Details

- CSIRO Mk3L model version 1.2 (Phipps, 2010).
- Atmospheric component - CSIRO Mk3 model (Gordon et al., 2002).
- ***Rhomboidal 21 resolution***, 18 vertical levels.
- Cumulus convection scheme (Gregory and Rowntree, 1990) and a prognostic stratiform cloud scheme (Rotstayn, 1997, 1998, 2000).
- The radiation calculations treat longwave and shortwave radiation separately, and include the effects of CO_2, ozone, water vapour and clouds.
- Ozone concentrations - Atmospheric Model Intercomparison Project (AMIP II) recommended dataset (Wang et al., 1995).
- A multi-layer dynamic-thermodynamic sea ice model and a land surface model are included.

Atmosphere Model simulations

- 5 numerical simulations forced by the observed monthly mean HADISST dataset (Rayner et al., 2003) from 1870-2010 and historical time-evolving carbon dioxide concentrations.
- The ensemble members are constructed perturbing the initial conditions.
- Although the atmospheric simulations incorporates the results of the multi-layer dynamic-thermodynamic sea ice model (not forced by the observed HADISST sea ice dataset), the simulated sea ice concentration (fraction) captures very well the observed concentration.

Definition of HC Intensity (HCI) index

According to Tanaka et al. [2004], the HC is contained in the zonal-mean field of the velocity potential,

$$[X(t,y)]$$

brackets indicate zonal averaging, t and y represent time and latitude.

- The HCI index - difference between the positive and negative peaks of the zonal mean velocity potential at 200 hPa level.
- 6 strong/8 weak HC cases from the 1979-2010 time series: selected considering the value of the difference between the positive and negative peaks of the zonal mean velocity potential, with the criterion that the normalized HCI is larger (less) than 1 (-1).

ROSSBY WAVE SOURCE (RWS)

The changes in tropical forcing can be approximated by changes in the RWS.

Sardeshmukh and Hoskins (1988):

$$RWS = -\zeta D - \overrightarrow{V_\chi}.\nabla\zeta = -\nabla.(\overrightarrow{V_\chi}\zeta)$$

vortex stretching term (VS)

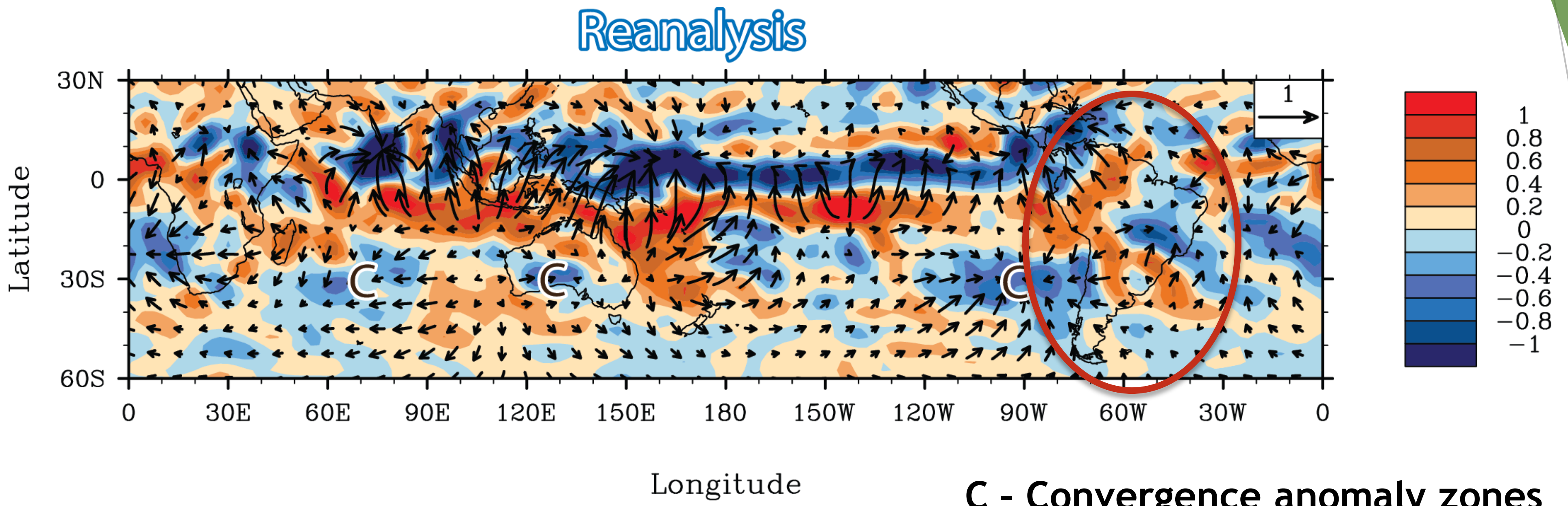
advection of absolute vorticity by divergent flow (AV)

Analysis method

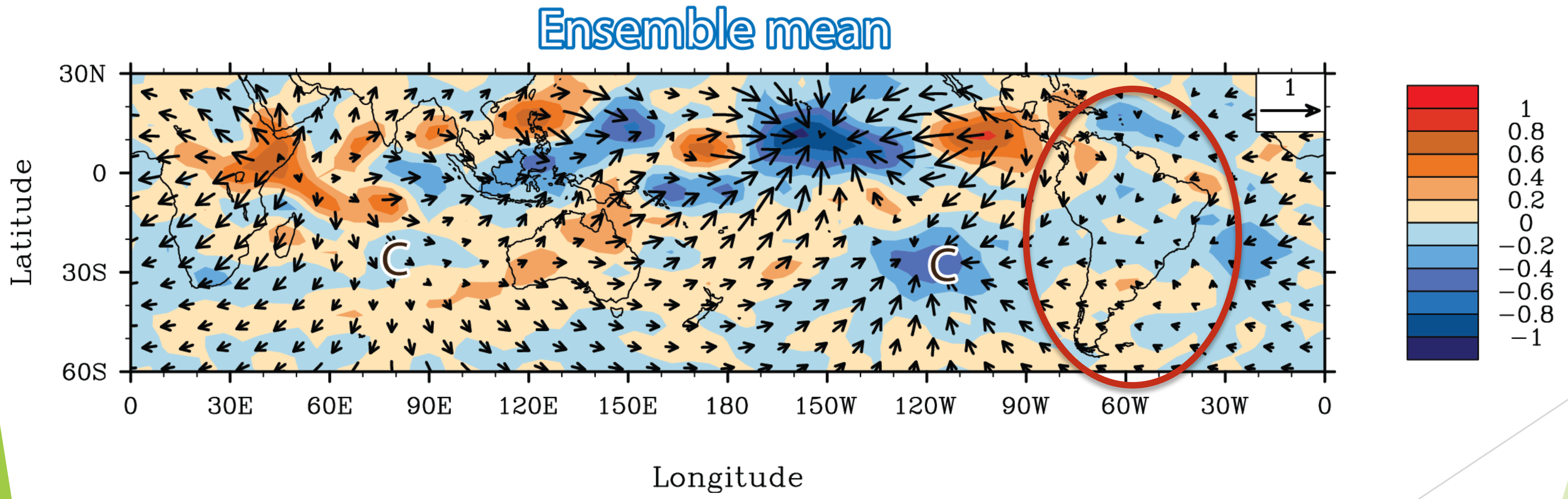
- Tyrrell et al. (1996) - Rossby wave source and mid-latitude circulation responses at upper levels associated with tropical variability has been considered.

  - The June-July-August (JJA) climatology - winter season the circulation modes are stronger.
  - 200 hPa level - divergence has its maximum amplitude at this level.

3. RESULTS – WEAK HC CASES

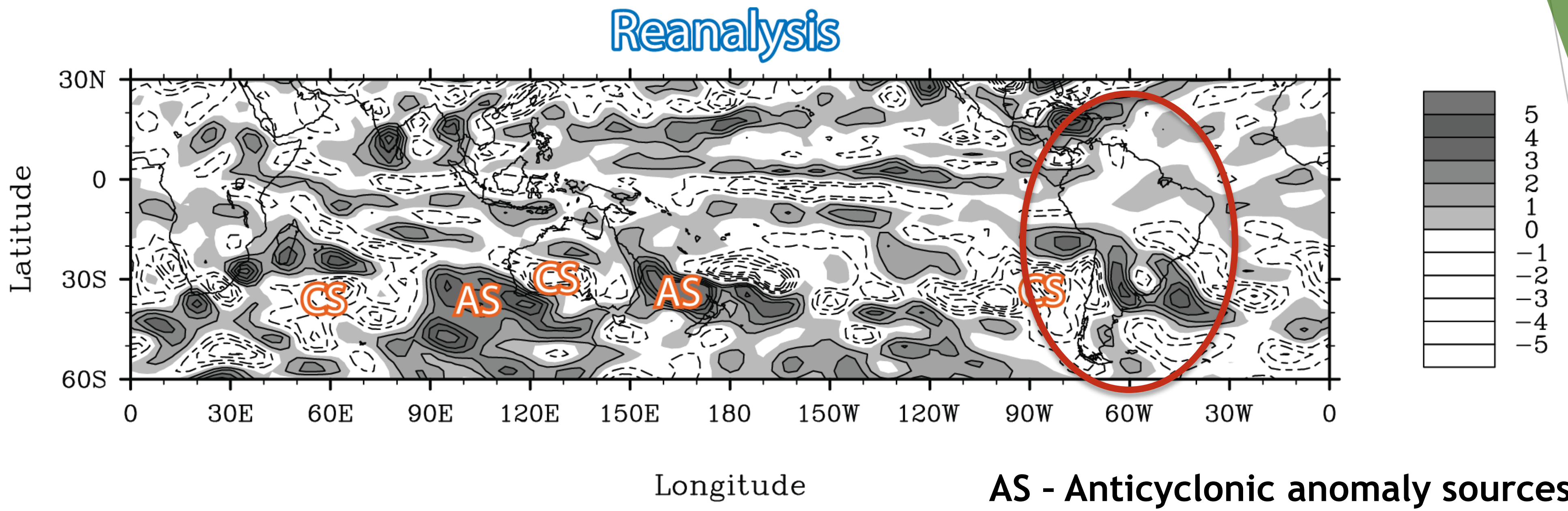


C - Convergence anomaly zones

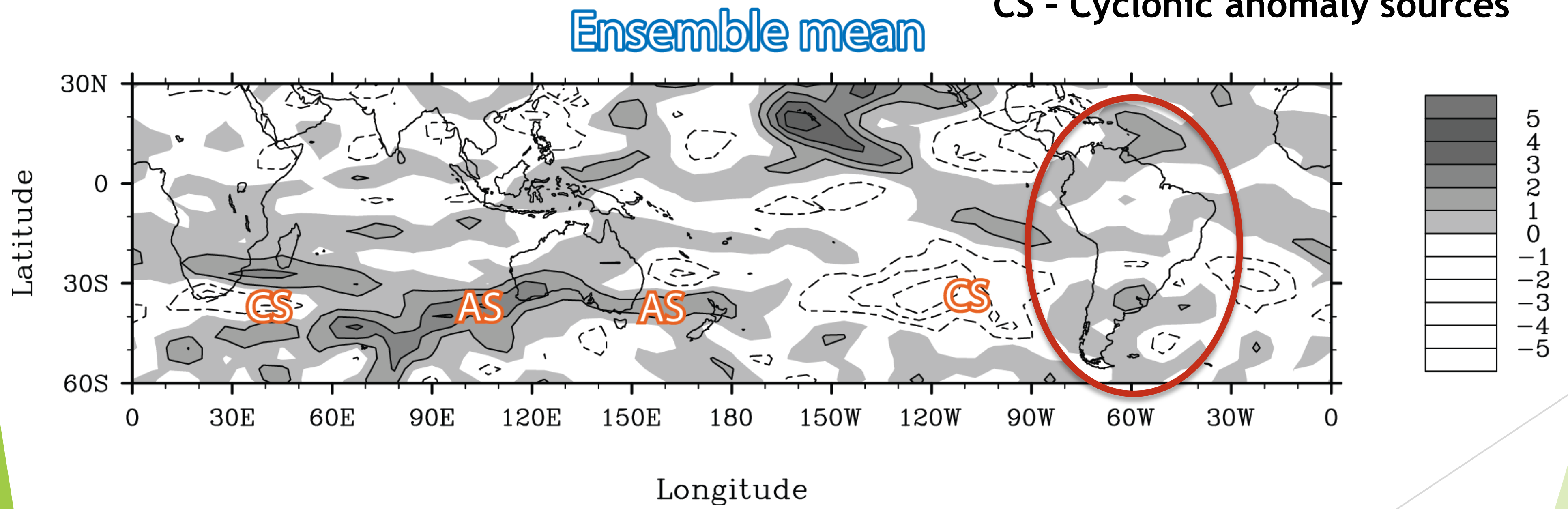


Anomaly divergence (x 10^{-6} s^{-1}) with divergent wind vectors at 200 hPa in JJA.

3. RESULTS – WEAK HC CASES

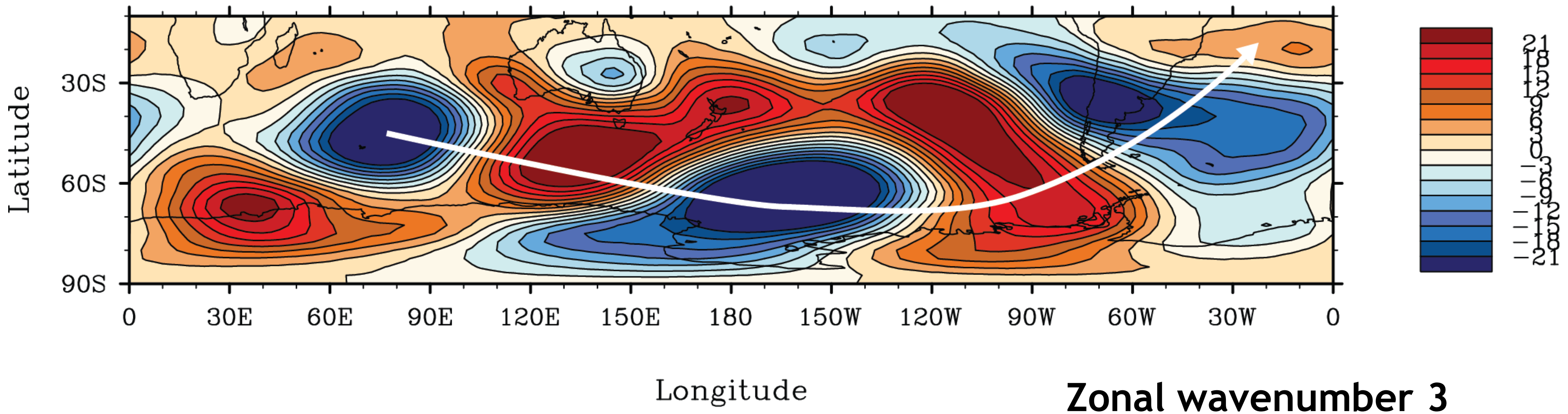


AS – Anticyclonic anomaly sources
CS – Cyclonic anomaly sources



Anomaly RWS (x 10^{-11} s^{-2}) at 200 hPa in JJA.

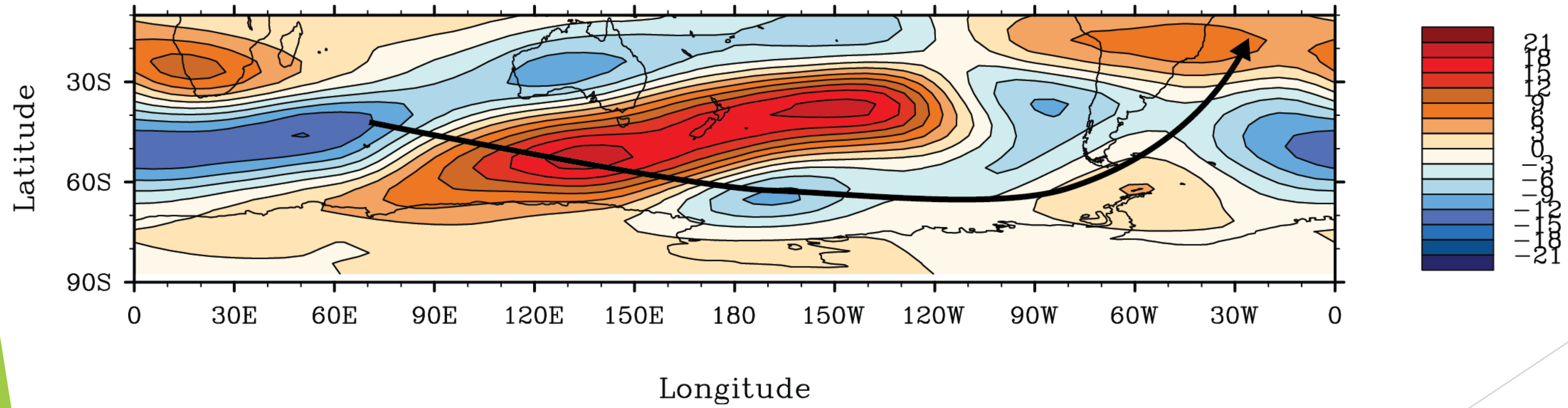
Reanalysis



Zonal wavenumber 3

Same signal at 500 hPa.

Ensemble mean



Anomaly stationary wave geopotential height (m) at 200 hPa in JJA.

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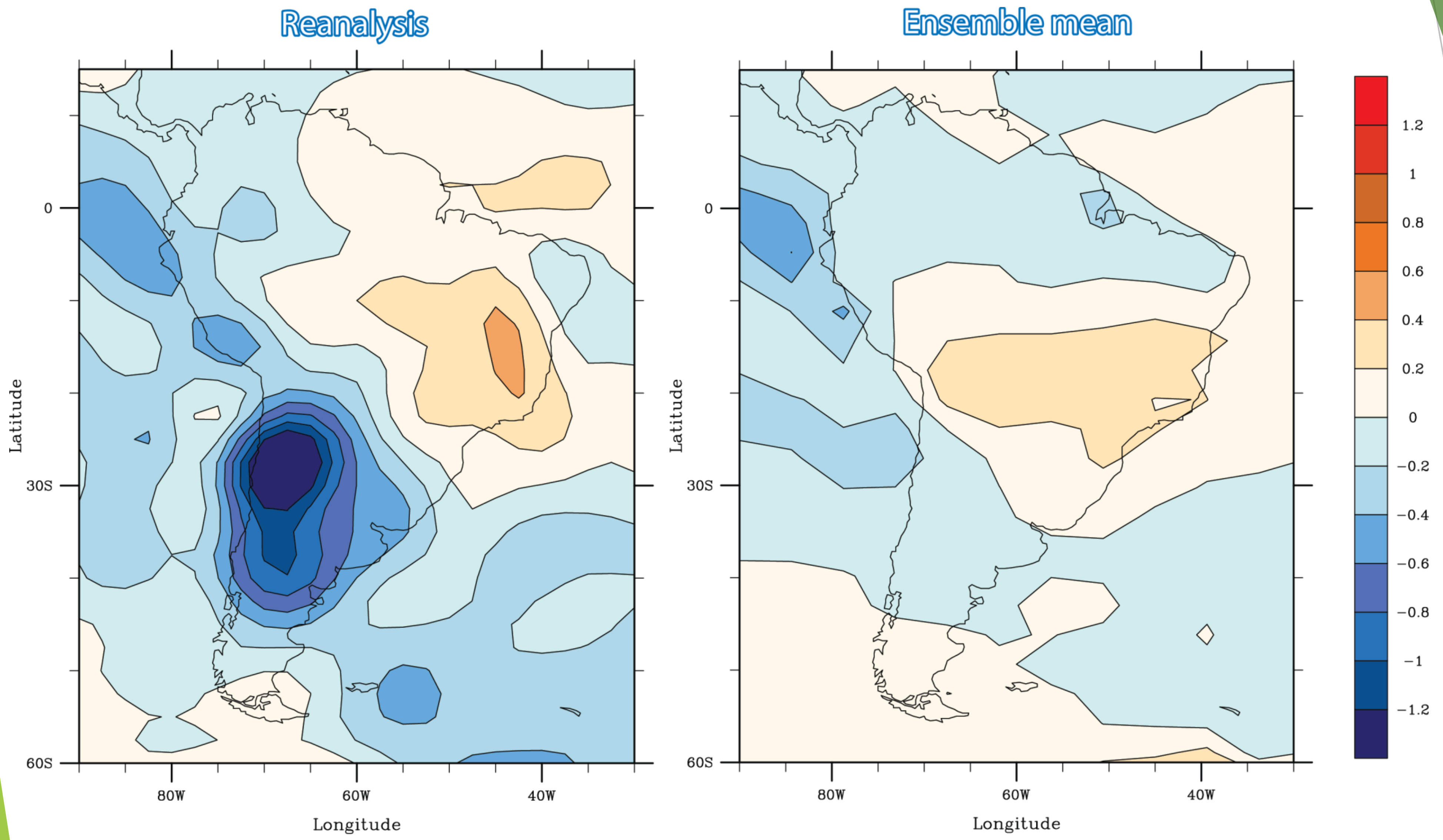
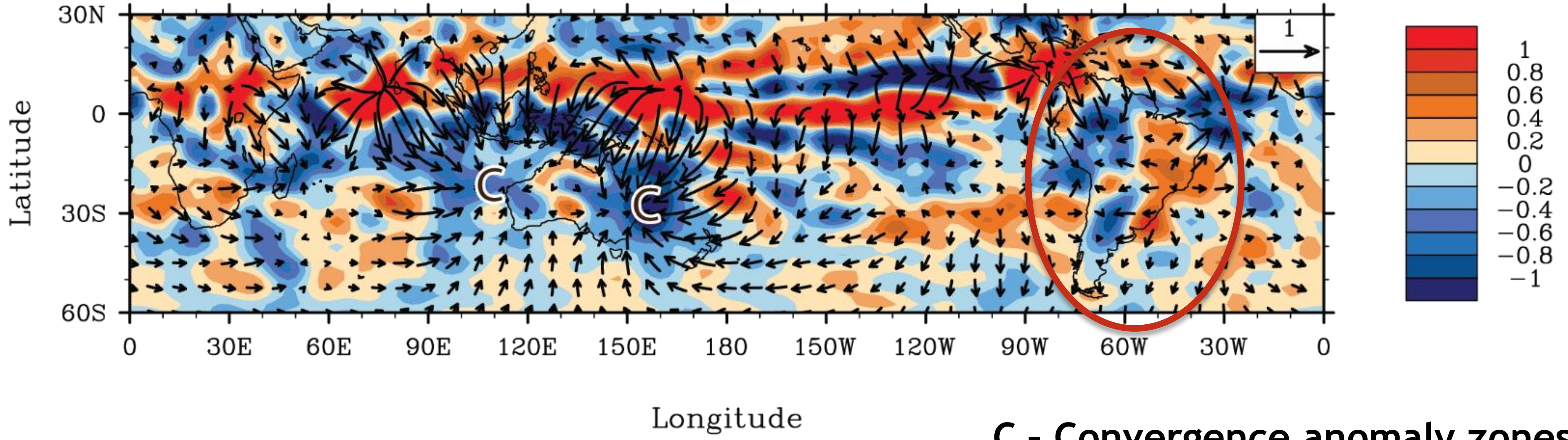


Anomaly air temperature (K) at 1000 hPa in JJA. **Same signal at 925 hPa.**

+ Anomalies – Midwest Brazil, Southern Chile and Argentina.
- Anomalies – Colombia, Equador, Peru, most of Argentina and Chile.

4. RESULTS – STRONG HC CASES

Reanalysis



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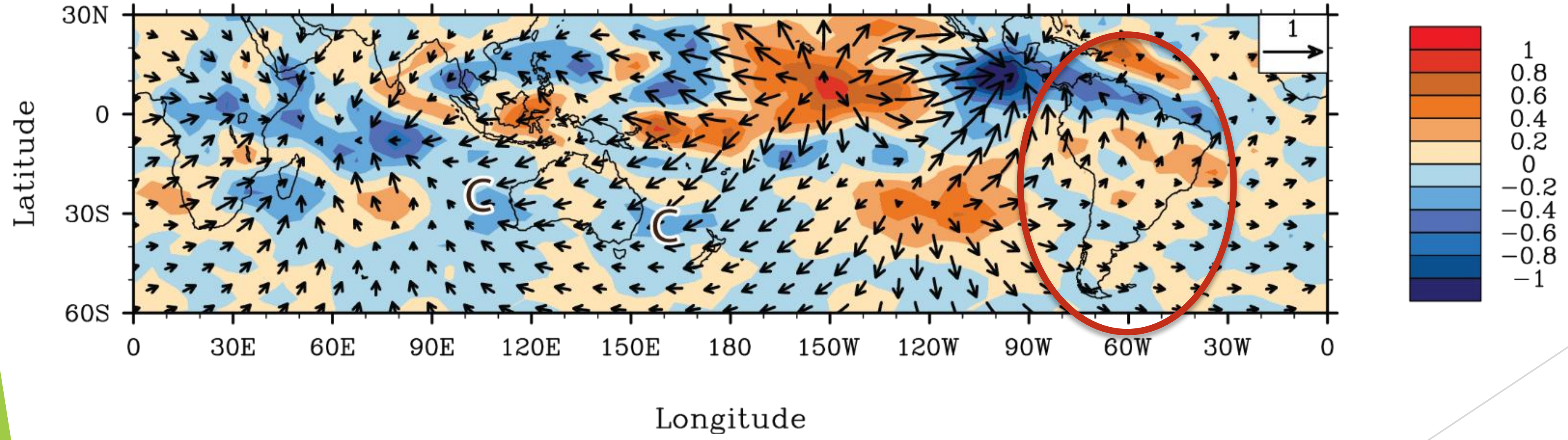

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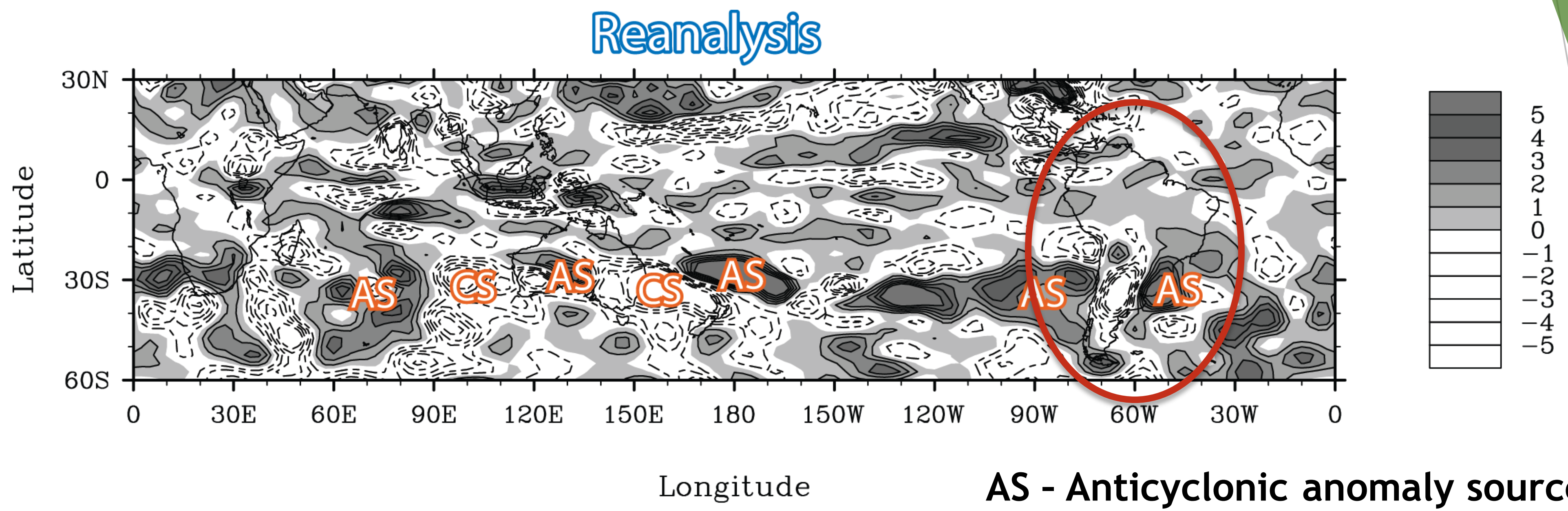

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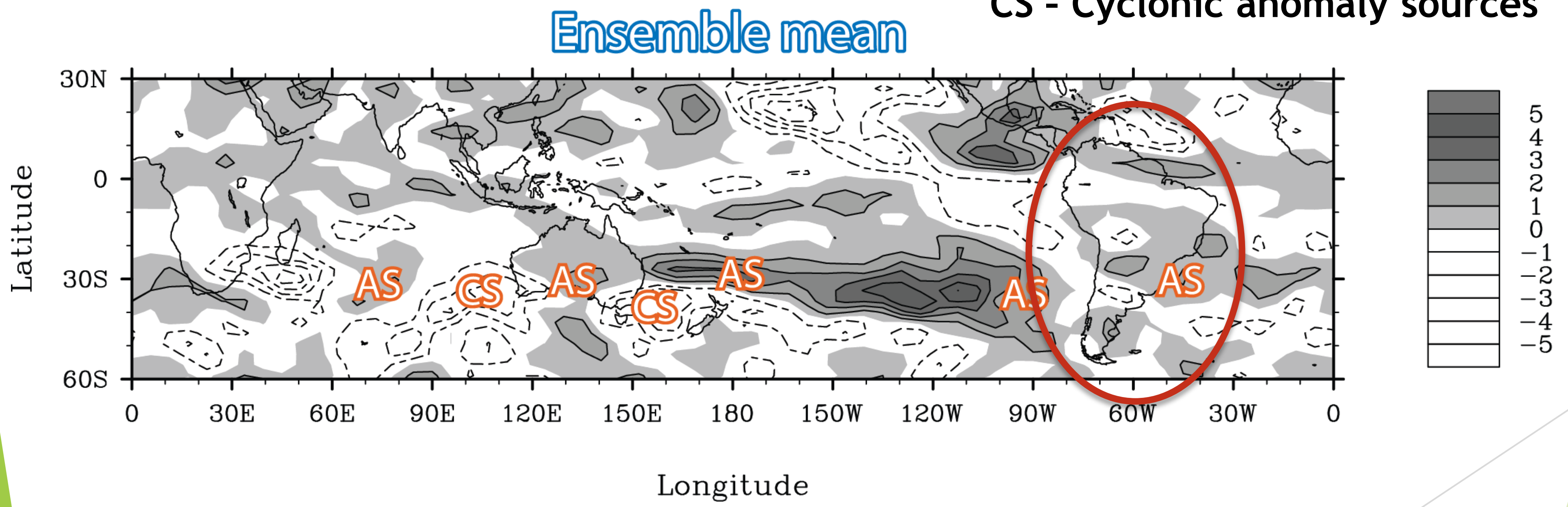

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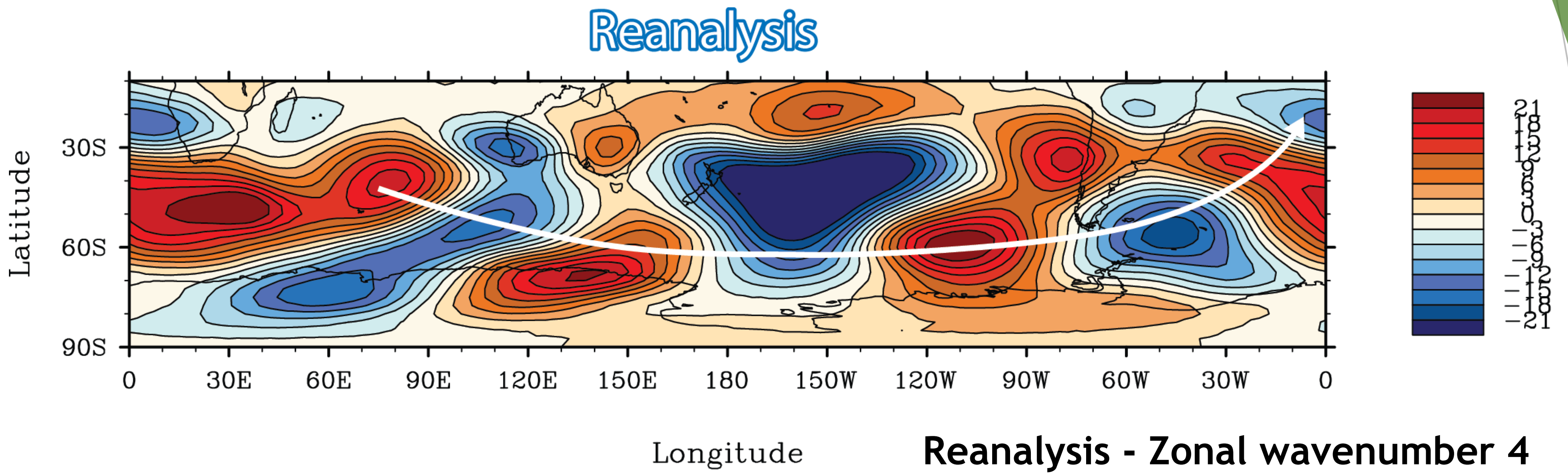
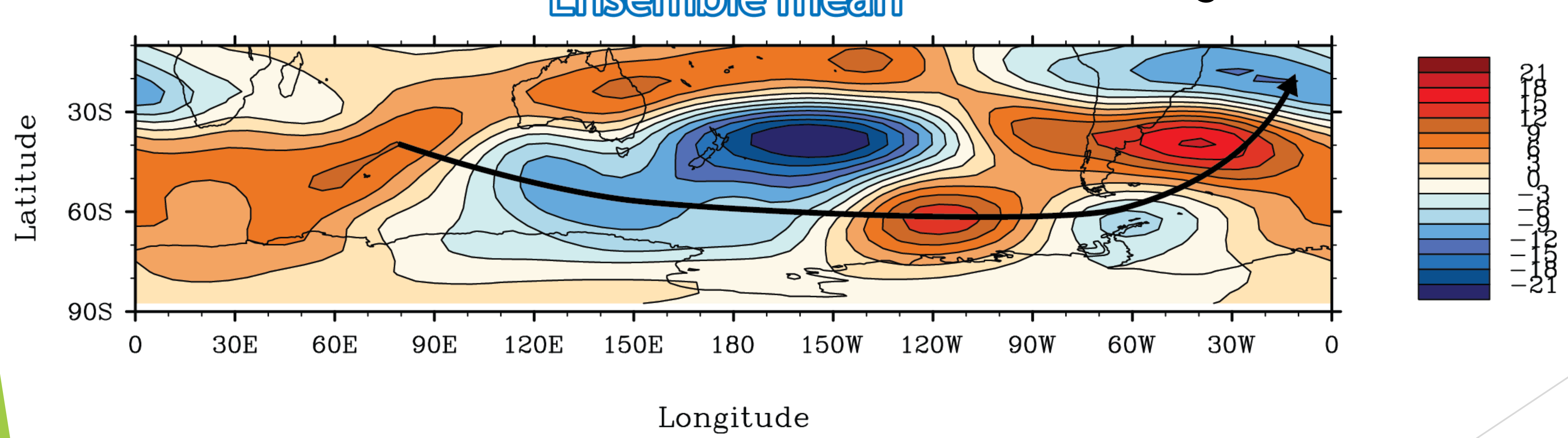


Reanalysis - Zonal wavenumber 4
Ensemble mean - Zonal wavenumber 3
Same signal at 500 hPa.



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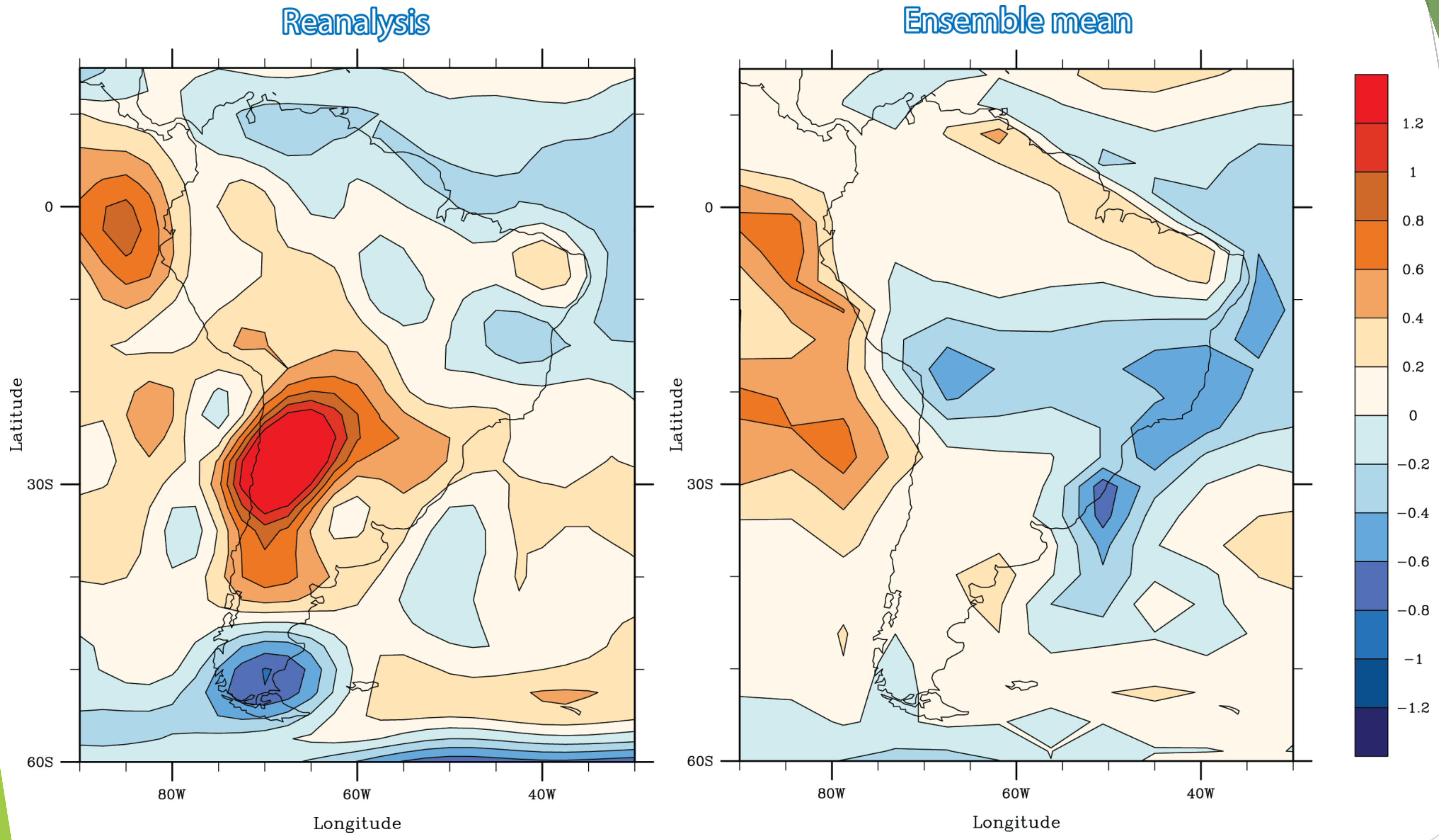

Anomaly air temperature (K) at 1000 hPa in JJA. Same signal at 925 hPa.

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+ Anomalies – Equador, Peru, most of Argentina and Chile.

MAIN FINDINGS

- The location of the RWS forcing is immediately over the high latitude downward branch of the local Hadley cell, which is associated with upper-level convergence zones.
- Changes in the intensity of HC generated an equivalent-barotropic Rossby wave train with significant effects for all the SH.
- Weak HC cases: wave train emanating from the subtropical central-west Indian Ocean in an arc-like route reaching the north of South America- zonal wavenumber three in the polar jet waveguide.
- Strong HC cases: wave train also trapped inside the polar jet waveguide emanating from subtropical central-east Indian Ocean and reaching the subtropical west coast of Africa - zonal wavenumber four (observational data).
- HC weakening: cold and rainy winter - Colombia, Equador, Peru, Argentina, Chile and warm and dry winter - Midwest Brazil, Southern Chile and Argentina. A pattern almost opposite was observed when the HC strengthens.

CONCLUSIONS

- **The stand-alone atmospheric CSIRO Mk3L model forced by observed SST and carbon dioxide concentrations showed some discrepancies between the observed data, especially around the Australian continent. However, on the South America, the model could skillfully reproduce the broad features of the wave trains and the observed temperature anomalies, although with reduced magnitude.**
- **The link between tropical and extra-tropical circulations is complex and the nonlinear characteristics, like thermodynamical features, dependence of the basic state flow, dynamical factors and interaction with transients, are not yet completely understood.**

MAIN REFERENCE PAPER

- Freitas and Ambrizzi - **Changes in the Austral Winter Hadley Circulation and the Impact on Stationary Rossby Waves Propagation**, Advances in Meteorology, 2012.

Thank you for your attention
and for the organize committee
for the invitation