The western Colombia low-level jet and its simulation by CMIP5 models

Juan P. Sierra, Jhoana Agudelo, Paola A. Arias and Sara C. Vieira

Grupo de Ingeniería y Gestión Amiental (GIGA), Escuela Ambiental, Facultad de Ingeniería, Universidad de Antioquia, Medellín, Colombia

1. Motivation

Importance of Choco low-level jet

- Choco jet transports important quantities of moisture from the Pacific ocean into western Colombia **(Poveda and Mesa, 1999),** especially during SON **(Sakamoto et al. 2011; Arias et al. 2015).**
- The interaction of this jet with the ITCZ, the CLLJ, and the EMEJ, induces the formation of MCSs **(Sakamoto et al. 2011).**
- The MCSs contribute to 70% of annual precipitation over the western part of Colombia **(Zuluaga and Poveda, 2004).**

Choco low-level jet and climate change

- The Choco jet was stronger during the last glaciation due to an increased SST gradient, turning western Colombia wetter for this period **(Martínez et al. 2003).**
- **What could happen with the Choco jet under a warmer climate?**
- **The first step is the representation of the present time features of this jet.**

2. Datasets

- ERA-Interim reanalysis **(Dee et al. 2011).**
- Global Precipitation Climatology Project (GPCP) **(Adler et al. 2003).**
- TRMM rainfall data 3B43 V7 **(Huffman et al. 2007).**
- ETOPO1 data from NOAA **(Amante and Eakins, 2009).**
- 26 coupled and 11 uncoupled Global Climate Models from the CMIP5 project.

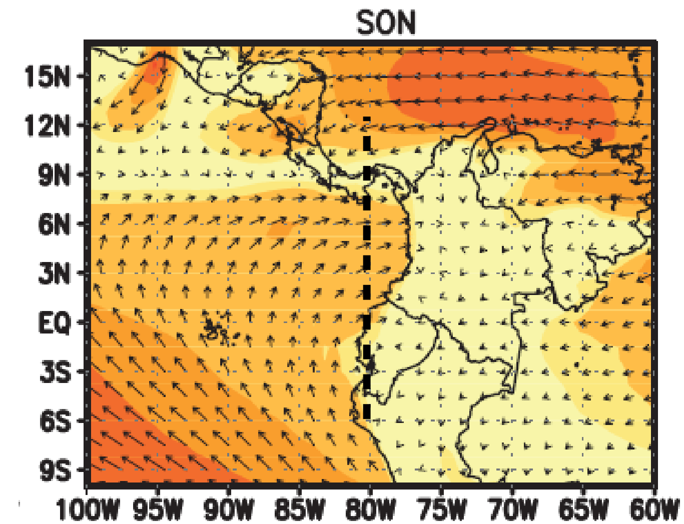
3. Methods

- GCM **historical experiment** of the CMIP5 runs.
- **Time domain:** 1979-2005.
- Use of **AMIP** and **CMIP** models.
- Original models resolution and bilinear interpolation for ensemble means (2.8°x2.8°).
- Quantify the quality of model simulations using RMSE, Pattern and Pearson Correlation Coefficients **(Taylor, 2001).**
- Cluster Analysis for model classification **(Wilks, 2011).**
- Factor Analysis for dimension reduction **(Rencher, 2002).**

4. Observations

Basic features of the Choco jet

- Results as an inversion of the easterly winds.
- Choco jet is centered at 5°N and 80°W.
- The jet core is at 925hPa.
- This jet has an annual cycle with peaks during Oct-Nov and a minor activity during Feb-March **(Poveda and Mesa, 2000).**



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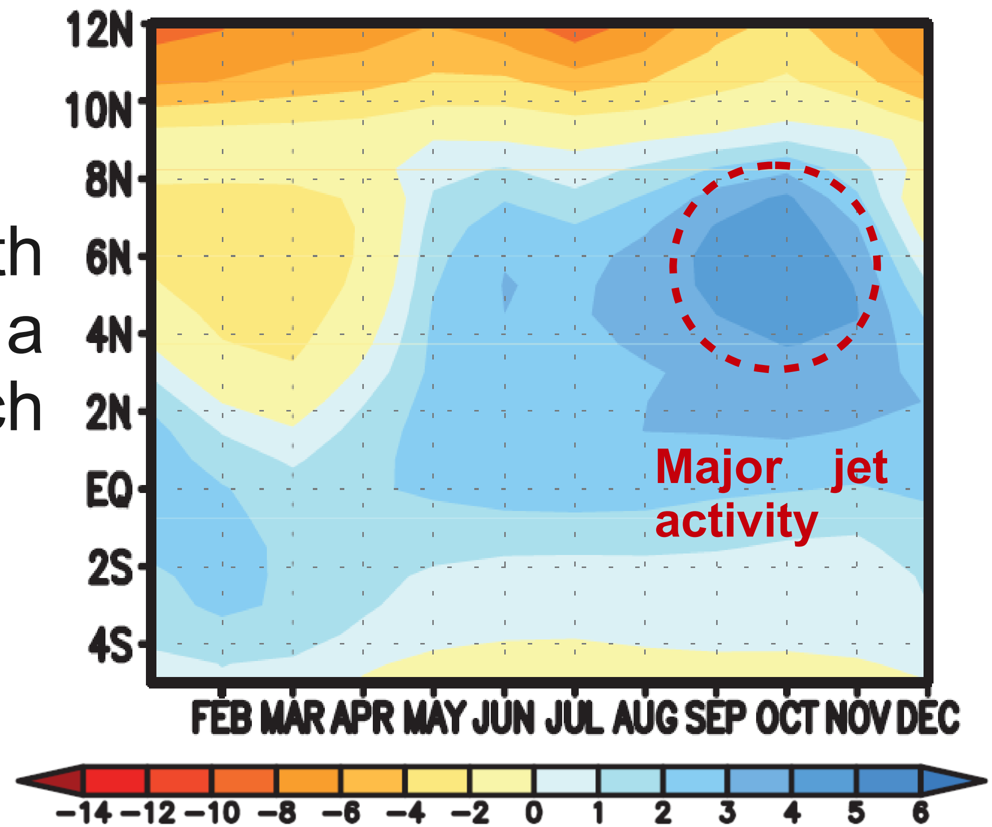


Fig. 1 Monthly climatology for 925hPa zonal wind annual cycle from ERA-Interim in m/s.

4. Observations

Basic features of the Choco jet

- This low-level jet exhibits a latitudinal amplification and deepening in the lower troposphere.

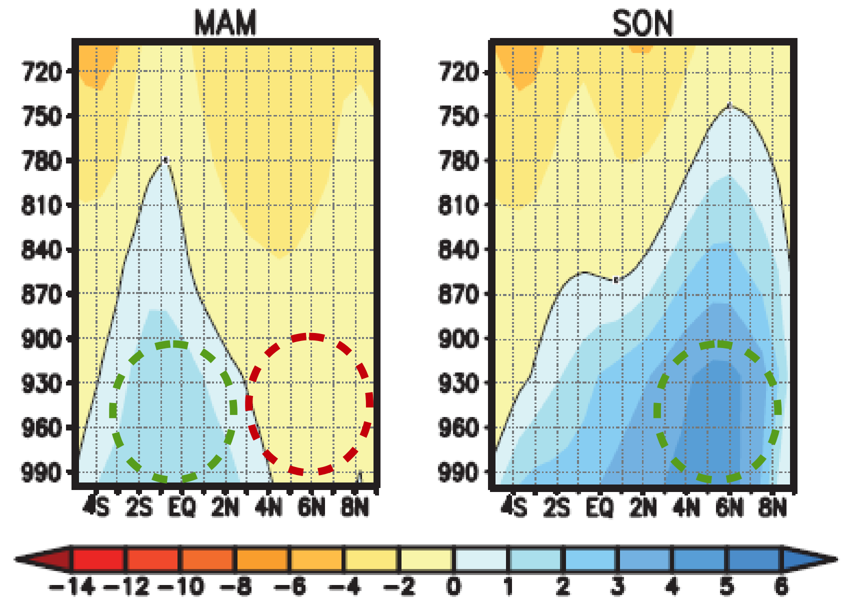


Fig. 2 Seasonal climatology for zonal wind from ERA-Interim in m/s. **Vertical structure of the jet.**

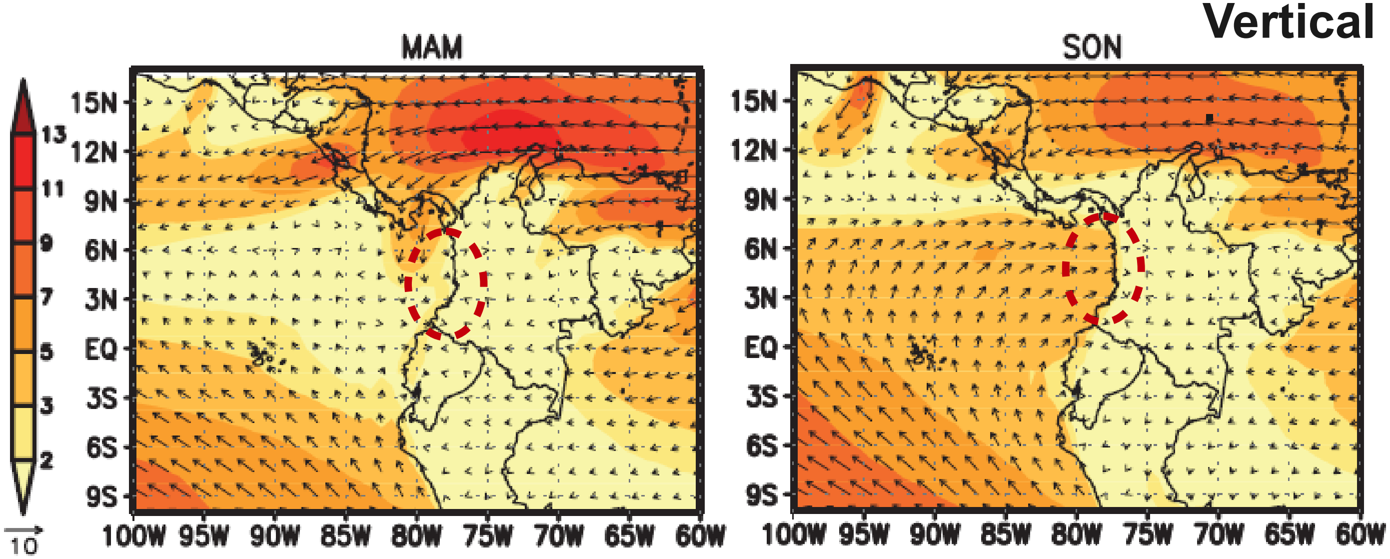


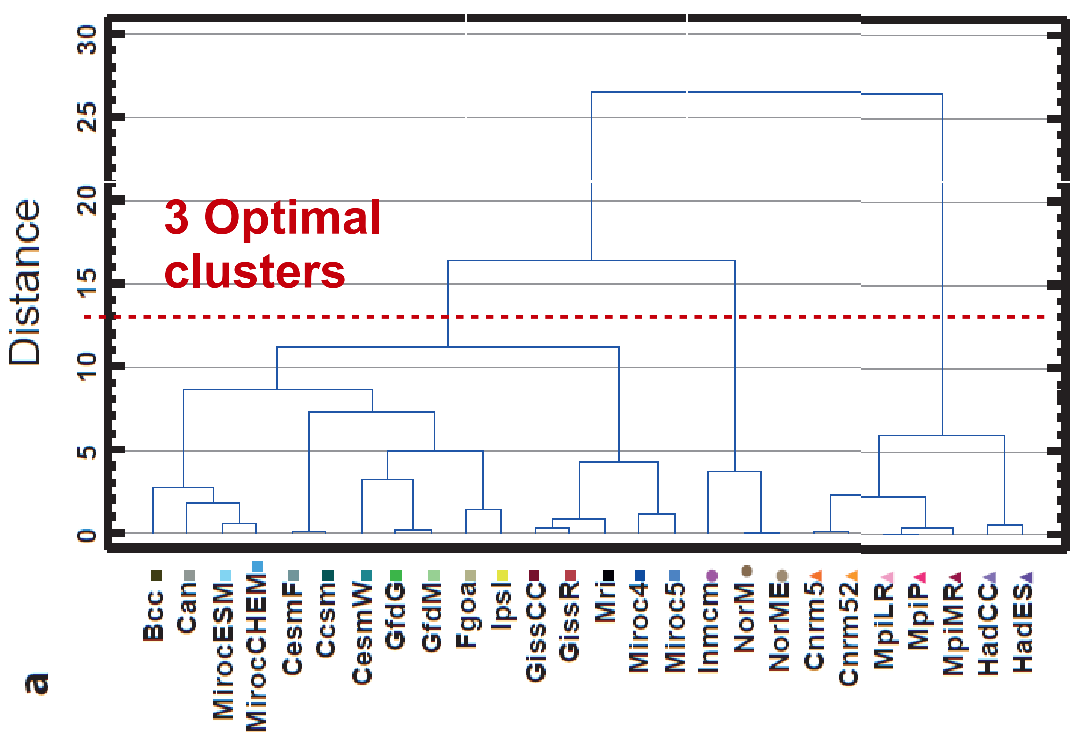
Fig. 3 Seasonal climatology for zonal wind at 925hPa from ERA-Interim in m/s. **Spatial distribution of the jet.**

Jet core

Latitudinal amplification and migration of the jet.

5. Cluster Analysis for Model Classification

- Use of **RMSE** and **PCC** of the **basic features** (**annual cycle, vertical structure and spatial distribution**) of the Chocó low-level jet as **indicators** of the **quality of model representation**.



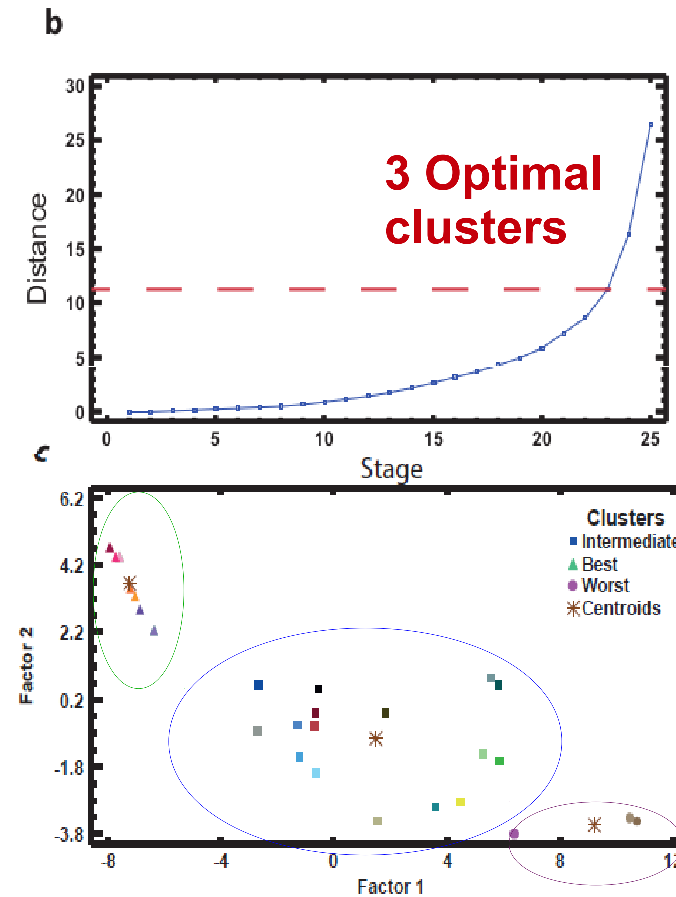
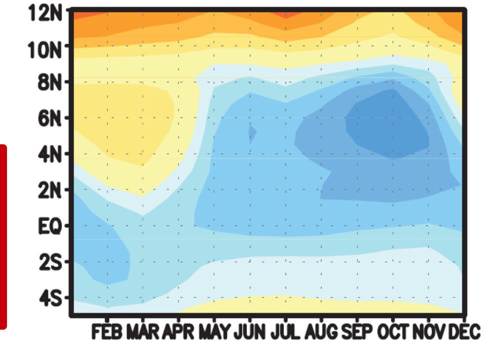


Fig. 4 Cluster analysis for model classification among Best, Worst and Intermediate models.

6. Results

6.1 Representation of the basic features of the Choco jet: Annual Cycle



Reference figure

- **Worst:** bias in the latitudinal location of the jet (southern). No Jet activity between April-May. **Major activity during August-October.**
- **Best and AMIP: major activity** of the jet **during August-October and** southern location between October and December.

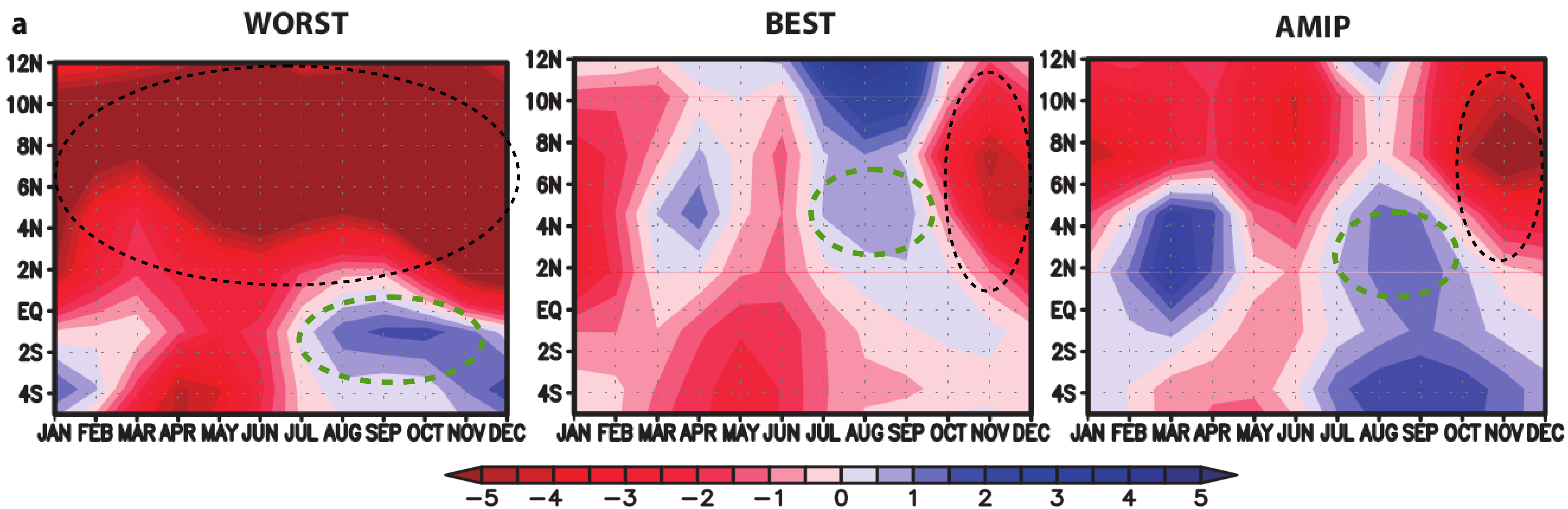
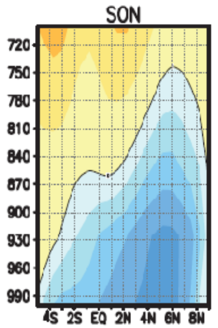


Fig. 5 Annual cycle differences of zonal winds from ERA-Interim at 81°W and 925hPa for Worst, Best and AMIP groups in m/s.

6.2 Representation of the basic features of the Choco jet: Vertical Strucure



Reference figure

- **Worst:** Shallower jet, especially during SON. Stronger zonal mid-tropospheric winds.
- **Best:** Good representation of the vertical depth during DJF and MAM, but shallower jet in SON. Slightly stronger zonal mid-tropospheric winds.
- **AMIP:** Northern jet during MAM. Stronger zonal mid-tropospheric winds particularly during MAM and JJA.

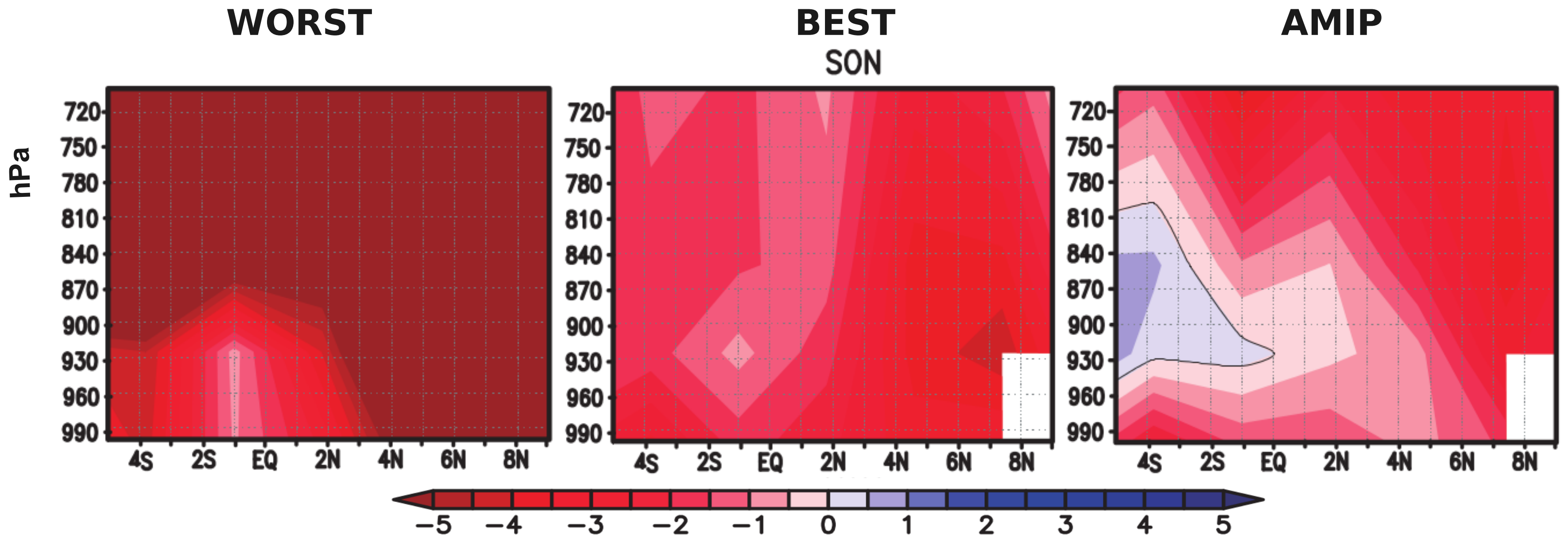
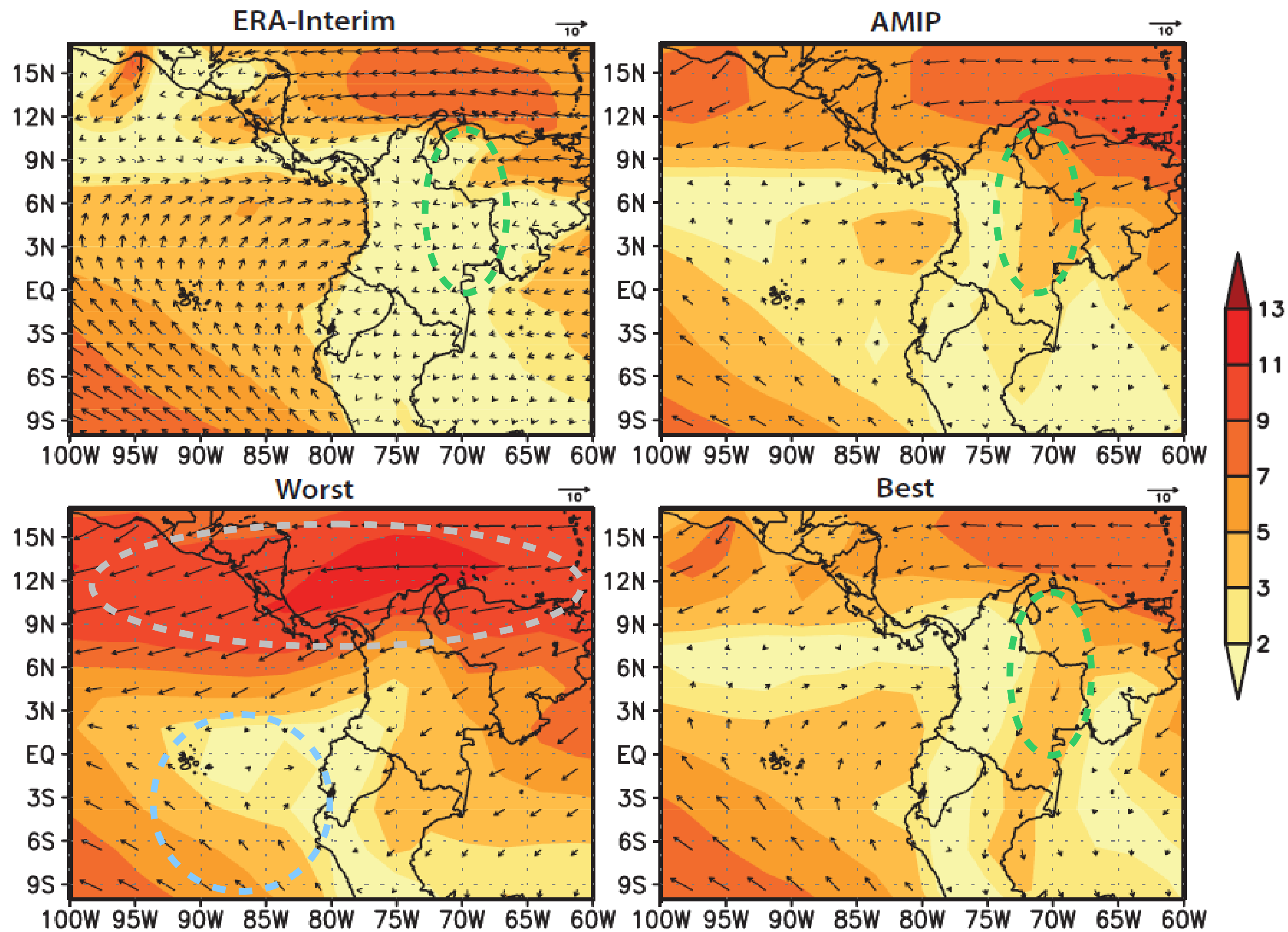


Fig. 6 Vertical structure of the Choco Jet (zonal wind differences from ERA-Interim (m/s)) at 1000-700 hPa, 81°W for Worst (left), Best (middle) and AMIP (rigth) models during SON.

6.3 Representation of the basic features of the Choco jet: Spatial Distribution



Change of winds direction due to topography

Overestimation of easterly winds

Underestimation of winds coming from the south

Fig. 7 Seasonal climatology for horizontal wind (m/s) at 925 hPa represented by ERA-Interim, Worst, Best and AMIP models during **SON**.

6.3 Representation of the basic features of the Choco jet: Spatial Distribution

- **Worst:** Stronger easterly winds over Caribbean sea and northeastern Pacific. Absence of the change in direction of horizontal winds due to topographic barrier. Underestimation of the winds coming from Peru and Ecuador coasts.
- **Best:** Horizontal shift due to topography. Better winds coming from Peru and Ecuador. Better location of the latitudinal range where westerly winds get into the continent.
- **AMIP:** Better representation during DJF and MAM and worse representation in JJA and SON.

6.4 Mechanisms that explain the existence of the Choco jet

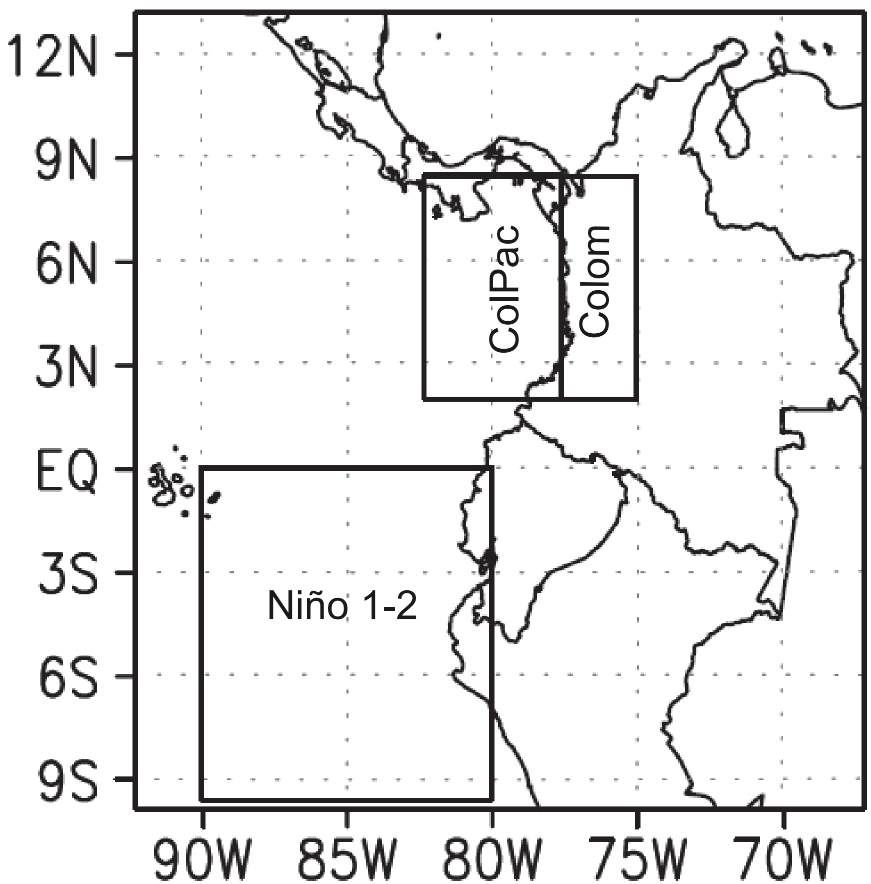
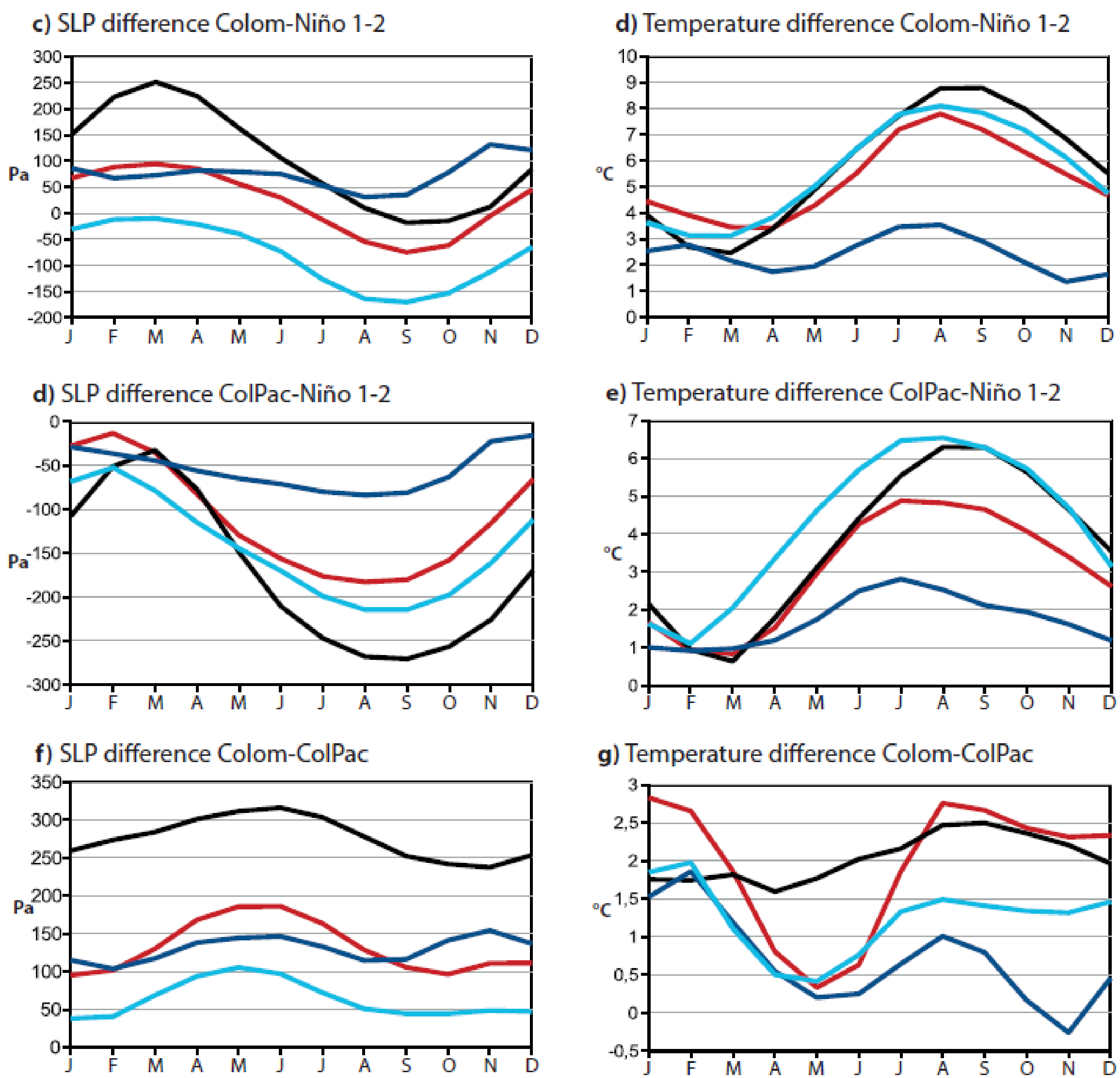
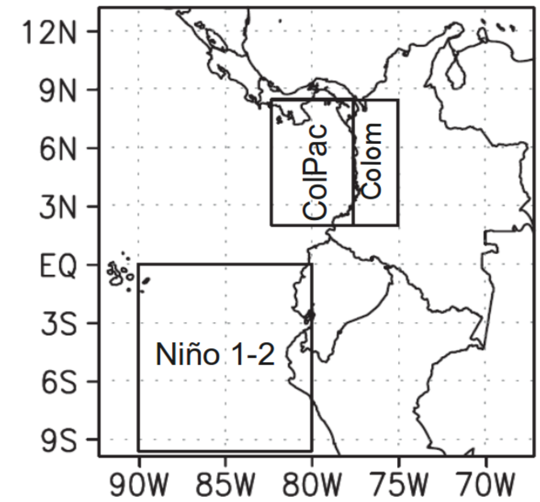


Fig. 8 Explicative gradient regions for temperature and sea level pressure for Choco jet. **(Poveda and Mesa 2000)**

- **Differences of temperature and sea level pressure among the regions.**
- **Topographic lifting.**
- Interaction with easterly winds.
- Change of Coriolis sign.
- Latent heat release in MCSs.

6.4 Mechanisms that explain the existence of the Choco jet





Reference figure

- Better representation for Best and AMIP models.
- Worst representation in differences between Colom and Colpac regions.
- Annual cycle peaks one month in advance.

Fig. 10 Annual cycle of regional differences for temperature and pressure at 1000hPa.

6.4 Mechanisms that explain the existence of the Choco jet

Model	RMSE (m)	Bias(%)
Bcc-csm1 (C)	611,831	-11,1797
CanESM2 (C)	494,165	41,9147
CESM1-FASTCHEM (C)	521,314	-8,31538
CESM1-WACCM (C)	730,977	-23,9894
CCSM4 (C)	521,314	-8,31537
CNRM-CM5 (C)	479,975	-1,43096
CNRM-CM5-2 (C)	479,975	-1,43096
FGOALS-g2 (C)	500,575	7,55261
GFDLESM2G (C)	367,183	12,5889
GFDLESM2M (C)	367,183	12,5889
GISS-E2-H-CC (C)	393,531	17,6405
GISS-E2-R (C)	379,234	20,4438
Inmcm4 (C)	680,243	-7,68865
IPSL-CM5B-LR (C)	560,368	-11,092
MIROC4h (C)	338,026	3,56711
MIROC5 (C)	559,667	-5,62478
MIROC-ESM (C)	530,732	6,26552
MIROC-ESM-CHEM (C)	530,732	6,26552
MPI-ESM-LR (C)	483,575	-2,23922
MPI-ESM-MR (C)	483,575	-2,23922
MPI-ESM-P (C)	483,575	-2,23922
MRI-CGCM3 (C)	429,469	2,25459
HadGEM2-CC (C)	551,007	-9,85687
HadGEM2-ES (C)	551,007	-9,85687
NorESM1-M (C)	730,972	-23,9922
NorESM1-ME (C)	730,972	-23,9922

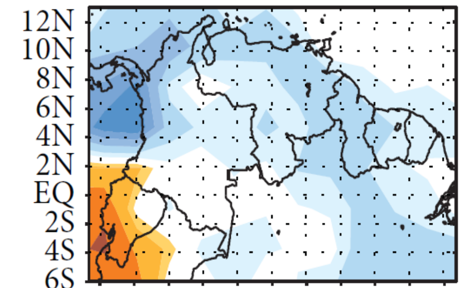
Table. 1 RMSE and bias for topography in the region 10°S-12°N, 85°-60°W.

Best

Worst

- **Best models** present a good topography representation.
- **Worst models** present a misrepresentation of topography.
- Underestimation of the topographic gradient.
- The low-level circulation is sensitive to the height of the Andes **(Saurral et al. 2014).**

6.5 Consequences of the representation of the Choco jet



Reference figure: Monthly correlations between Choco jet index and precipitation anomalies **(Sierra et al. 2015).**

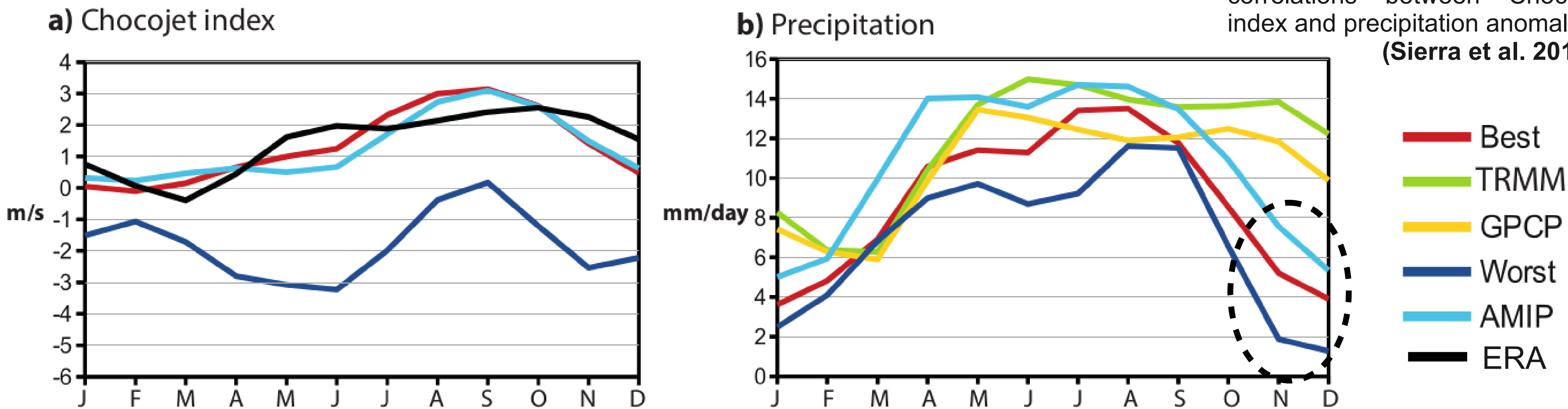


Fig. 11 Choco index annual cycle and precipitation annual cycle for western Colombia (80-76°W, 2°-9°N).

- Choco index is defined as the zonal wind average at 81°W, 925hPa between 5°S-7°N **(Poveda and Mesa, 2000).**
- A better representation of the Choco jet could be related with a better representation of precipitation annual cycle for western Colombia, especially during October-November-December.

7. Conclusions

- **All models** present the **existence of the westerly winds at the eastern tropical Pacific** during almost the entire year.
- Models present the **maximum activity** of the Choco jet **2-1 months earlier**. This error **comes from the atmospheric component of models**.
- Worst models tend to keep the jet further south, which seems to be related with a misrepresentation of the inter-hemispherical temperature differences.
- Models in general tend to present a **southward migration of the jet during SON and December**. **This error comes from the atmospheric component of models.**
- **Underestimation of the jet core velocities during most of the year.**

7. Conclusions

- Misrepresentation of the ocean-land temperature and pressure annual cycle differences.
- Topography representation can lead to a better representation of the jet.
- A better representation of the jet can improve the representation of precipitation over certain regions of Colombia.

8. Acknowledgments

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