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Warming and wetting signals emerging from analysis of changes in climate extreme indices over South America

María de los Milagros Skansi [a,*], Manola Brunet [b,c], Javier Sigró [b], Enric Aguilar [b], Juan Andrés Arevalo Groening [d], Oscar J. Bentancur [e], Yaruska Rosa Castellón Geier [f], Ruth Leonor Correa Amaya [g], Homero Jácome [h], Andrea Malheiros Ramos [i,j], Clara Oria Rojas [k], Alejandro Max Pasten [l], Sukarni Sallons Mitro [m], Claudia Villaroel Jiménez [n], Rodney Martínez [o], Lisa V. Alexander [p], P.D. Jones [c,q]

[a] Departamento Climatología, Servicio Meteorológico Nacional, 25 de Mayo 658 (C1002ABN), Ciudad Autónoma de Buenos Aires, Argentina
[b] Centre for Climate Change, Department of Geography, University Rovira i Virgili, Av. Catalunya, 35, 43071, Tarragona, Spain
[c] Climatic Research Unit, University of East Anglia, Norwich, NR4 7TJ, United Kingdom
[d] Instituto Nacional de Meteorología e Hidrología (INAMEH), Carretera Hoyo de la Puerta, Parque Tecnológico Sartenejas, Edificio INAMEH. Municipio Baruta, Estado Miranda, 1080 Venezuela
[e] Dpto. Biometría, Estadística y Computación, Facultad de Agronomía, UDELAR, Av. Garzón 780, Montevideo, CP.12900, Uruguay
[f] Unidad Climatologia, Institucion: Servicio Nacional de Meteorologia e Hidrologia (SENAMHI), Calle Reyes Ortiz No. 41 (Zona Central), La Paz, Bolivia
[g] Grupo de Gestión de Datos y Red Meteorológica, Subdirección de Meteorología, Instituto de Hidrología, Meteorología y Estudios Ambientales, IDEAM, Carrera 10 No. 20–30 Piso 6, Colombia
[h] Dpto. de Climatología, Instituto Nacional de Meteorología e Hidrología (INAMHI), Calle Iñaquito No. N36-14 y Corea, Codigo Postal No. 16-310, Quito, Ecuador
[i] Coordenação de Desenvolvimento e Pesquisa (CDP). Instituto Nacional de Meteorologia (INMET). Eixo Monumental, Via S1 Sudoeste. 70680-900, Brasília-DF, Brazil
[j] Geophysics Centre of Évora (CGE), University of Évora, Portugal. Rua Romão Ramalho, 59. 7000-671. Évora, Portugal
[k] Centro de Prediccion Numerica de la Direccion General de Meteorología, Servicio Nacional de Meteorologia e Hidrologia del Peru, Jr. Cahuide 785, Jesus Maria, Lima, Peru
[l] Direccion Nacional de Aeronautica Civil–Dirección de Meteorologia e Hidrología Gerencia de Climatologia e Hidrología, Departamento de Climatología, Cnel. Francisco Lopez 1080 c/ De La Conquista, Paraguay
[m] Meteorological Service Suriname, Magnesiumstraat 41, Paramaribo, Surinam
[n] Direccion Meteorológica de Chile, Subdepartamento de Climatología y Meteorología Aplicada, Seccion de Met. Aplicada — Oficina de Estudios, Av. Portales 3450, Estación Central, Santiago, Chile
[o] Centro Internacional para la Investigación del Fenómeno de El Niño (CIIFEN), Escobedo 1204 y 9 de Octubre, P.O. Box 09014237, Guayaquil, Ecuador
[p] Climate Change Research Centre and Centre of Excellence for Climate Systems Science, University of New South Wales, Sydney NSW 2052, Australia
[q] Center of Excellence for Climate Change Research/Dept of Meteorology, Faculty of Meteorology, Environment and Arid Land Agriculture, King Abdulaziz University, P. O. Box 80234, Jeddah 21589, Saudi Arabia

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ABSTRACT

Here we show and discuss the results of an assessment of changes in both area-averaged and station-based climate extreme indices over South America (SA) for the 1950–2010 and 1969–2009 periods using high-quality daily maximum and minimum temperature and precipitation series. A weeklong regional workshop in Guayaquil (Ecuador) provided the opportunity to extend the current picture of changes in climate extreme indices over SA.

Our results provide evidence of warming and wetting across the whole SA since the mid-20th century onwards. Nighttime (minimum) temperature indices show the largest rates of warming (e.g. for tropical nights, cold and warm nights), while daytime (maximum) temperature indices also point to warming (e.g. for cold days, summer days, the annual lowest daytime temperature), but at lower rates than for minimums. Both tails of night-time temperatures have warmed by a similar magnitude, with cold days (the annual lowest nighttime and daytime temperatures) seeing reductions (increases). Trends are strong and moderate (moderate to weak) for regional-averaged (local) indices, most of them pointing to a less cold SA during the day and warmer night-time temperatures.

* Corresponding author at: Departamento Climatología, Servicio Meteorológico Nacional, 25 de Mayo 658 (C1002ABN), Ciudad Autónoma de Buenos Aires, Argentina. Tel.: +54 11 51676767x18259/18273; fax: +54 11 51676709.
E-mail addresses: mms@smn.gov.ar (M.M. Skansi), manola.brunet@urv.cat (M. Brunet), javier.sigro@urv.cat (J. Sigró), enric.aguilar@urv.cat (E. Aguilar), jarevalo@inameh.gob.ve (J.A. Arevalo Groening), obent@fagro.edu.uy (O.J. Bentancur), yaruska@senamhi.gob.bo (Y.R. Castellón Geier), rcorrea@ideam.gov.co (R.L. Correa Amaya), hjacome@inamhi.gob.ec (H. Jácome), andrea.ramos@inmet.gov.br (A. Malheiros Ramos), clara@senamhi.gob.pe (C. Oria Rojas), max.pasten@meteorologia.gov.py (A.M. Pasten), sukarnimitro@yahoo.com (S. Sallons Mitro), cvilla@meteochile.cl (C. Villaroel Jiménez), r.martinez@ciifen-int.org (R. Martínez), l.alexander@unsw.edu.au (L.V. Alexander), P.Jones@uea.ac.uk (P.D. Jones).

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northeastern Brazil
western South America
southeastern South America

Regionally-averaged precipitation indices show clear wetting and a signature of intensified heavy rain events over the eastern part of the continent. The annual amounts of rainfall are rising strongly over south-east SA (26.41 mm/decade) and Amazonia (16.09 mm/decade), but north-east Brazil and the western part of SA have experienced non-significant decreases. Very wet and extremely days, the annual maximum 5-day and 1-day precipitation show the largest upward trends, indicating an intensified rainfall signal for SA, particularly over Amazonia and south-east SA. Local trends for precipitation extreme indices are in general less coherent spatially, but with more general spatially coherent upward trends in extremely wet days over all SA.

1. Introduction

The study of extreme weather and climate events is a current topic of higher scientific and societal interest. It is being fuelled by relevant scientific communities, including various climatological branches that assess climate change (e.g. observational, modeling, adaptation and impact sectors). This issue has been addressed recently by the Intergovernmental Panel on Climate Change (IPCC, 2012) in the Special Report on Extremes (SREX). This has provided the most comprehensive global review and assessment on the relation between climate extremes, their impacts and the strategies to manage associated perils.

A number of issues, however, constrain our current understanding and scientific confidence in the observed changes in extremes. Among others, availability and accessibility of long-term and high-quality climate series at the relevant time scales for assessing extremes (e.g. daily and sub-daily) is one of the most serious gaps, particularly over some regions of the world (often called climate-data-sparse regions), such as most of South America. The availability of climate series is also limited temporally, since for most of the world the length of digitized daily climate series (e.g. for temperature and precipitation) only goes back in time to the mid-20th century and for many regions is restricted to the 1970s onwards. In addition, there are also concerns regarding the quality and homogeneity of the available series, which could compromise the robustness of assessed changes. Many countries also restrict access to their higher temporal resolution time-series. In short, the quality and quantity of accessible climate series still limit our understanding of the observed changes in climate extremes, particularly over data-sparse regions (Trenberth et al., 2007: Appendix 3.B.2).

A number of international groups have made major efforts to advance both knowledge of global changes in climate extremes and to promote the recovery and development of climate data (i.e. ensuring data quality and homogeneity) over data-sparse regions. In this regard, the ETCCDI[1] has largely contributed to this effort by advancing knowledge on changes in climate extremes through the formulation of a suite of 27 core climate extreme indices calculated from daily temperature and precipitation data (http://cccma.seos.uvic.ca/ETCCDI/list_27_indices.shtml). They have also promoted the analysis and monitoring of extremes around the world through organizing regional workshops in data-sparse regions that have involved scientists from National Meteorological and Hydrological Services (NMHS) as part of ETCCDI's two-pronged approach (Peterson and Manton, 2008, p. 1266).

Contributions from the ETCCDI to filling in gaps in data-sparse regions and enhancing analyses of the global picture of changes in extremes (Trenberth et al., 2007, based on Alexander et al., 2006) have helped to improve knowledge and understanding about how and how much climatic extremes are changing under climate change. However, the network of stations used in global analysis (e.g. Alexander et al., 2006; Vose et al., 2005 or Brown et al., 2008), are not globally uniform and contain irregular or limited data over northern Latin America and South America as a whole, Africa, parts of Australia, India, the Middle East and Southern Asia, which restricts our ability to estimate changes in extremes over these regions (Seneviratne et al., 2012: 123).

For South America (SA hereafter), some effort has been made to assess changes in climate extremes based on temperature and precipitation station data at the daily scale (for temperature extremes: Vincent et al., 2005; Alexander et al., 2006 and for precipitation extremes: Haylock et al., 2006; Khan et al., 2007; Sheffield and Wood, 2008; Grimm and Tedeschi, 2009; Dai, 2011; Mo and Berbery, 2011).

Parts of SA have been more intensively explored, such as SE SA for observed changes in temperature extremes (e.g. Rusticucci and Barrucand, 2004; Barrucand et al., 2008; Marengo and Camargo, 2008; Rusticucci and Renom, 2008; Marengo et al., 2009; Renom, 2009; Tencer, 2010; Rusticucci, 2012) or for precipitation extremes (e.g. Dufek and Ambrizzi, 2008; Dufek et al., 2008; Marengo et al., 2009; Pscheidt and Grimm, 2009; Penalba and Robledo, 2010; Llano and Penalba, 2011; Teixeira and Satyamurty, 2011). Other sub-regional studies are focused on NE Brazil for precipitation extremes (e.g. Santos and Brito, 2007; Silva and Azevedo, 2008; Santos et al., 2009) and over western SA for temperature extremes (Falvey and Garreaud, 2009) and for precipitation extremes (Dufek et al., 2008).

From these studies, there is a clear geographical imbalance in the assessments of one or another part of SA and in the number of stations employed. Most previous studies have focused on southern SA, with limited studies and data over the northern half of SA. Most analyses however point to observed changes in temperature extremes consistent with warming when averaged over the whole continent but with regional variations (Vincent et al., 2005: 5016–5020). However, while extreme indices based on minimum (i.e. night-time) temperature have warmed, those based on maximum (i.e. daytime) temperature show little change or have cooled, particularly over southern SA (Rusticucci, 2012, pp. 4–6).

The scientific confidence in the observed changes over SA, therefore, ranges from low to medium, depending on the region analyzed (Seneviratne et al., 2012: Table 3.2, p. 194). There is low confidence in the assessed changes in extremes based on either daily maximum or minimum temperature data over the northern half of SA, including Amazonia, due to the irregular network in these regions. In the southern half of SA (including NE Brazil, south, SE and west Coast of SA) there is medium confidence in the estimated extreme temperature trends. In the case of heat waves and warm spells, the confidence is low over all SA, including southern SA, due to either insufficient evidence or to spatially varying trends.

A similar uncertain picture is apparent when assessing changes in precipitation extremes over all SA, due to both the scarcity of studies and spatially incoherent trends in either heavy events (e.g. those defined as daily precipitation >95th or 99th percentiles) or in dryness (e.g. consecutive dry days — CDD, Palmer Drought Severity Index – PDSI – indices) reducing the scientific confidence in the estimated trends. There is medium confidence that there have been increases in heavy precipitation events over Amazonia and many parts of NE Brazil, but a few areas in the west (W) coast of SA indicate decreases or mixed

[1] Joint World Meteorological Organization (WMO) Commission for Climatology (CCl)/World Climate Research Programme (WCRP) project on Climate Variability and Predictability (CLIVAR)/Joint WMO–Intergovernmental Oceanographic Commission of the United National Educational, Scientific and Cultural Organization (UNESCO) Technical Commission for Oceanography and Marine Meteorology (JCOMM) Expert Team on Climate Change Detection and Indices (ETCCDI: http://www.clivar.org/organization/etccdi).