UNIVERSIDAD DE COSTA RICA

(Hydro)climatological studies of climate change and variability in Central America.

Hugo G. Hidalgo[1,2]

(hugo.hidalgo@ucr.ac.cr)

1-School of Physics, University of Costa Rica, 2-Center for Geophysical Research, University of Costa Rica

CORDEX Central America and South America Training Workshop on Downscaling Techniques

June 25-27th 2018

CIGEFI

ESCUELA DE FÍSICA

Acknowledgements

- Thank you to CORDEX CAM/SAM Training Workshop organizers and sponsors for funding this visit.
- HH partially funded by projects 805-B3-413, B4-227, B3-600, B6-143 (Vice-presidency of research-UCR, CONICIT and MICITT), B0-810 and A4-906.
- Thank you to the School of Physics and Center for Geophysical Research

ESCUELA DE FÍSICA

CIGEFI

Characteristics of Central American climate

Climate regimes

UNIVERSIDAD DE COSTA RICA

Two well defined precipitation regimes: Pacific and Caribbean slopes

MSD: Mid-summer Drought

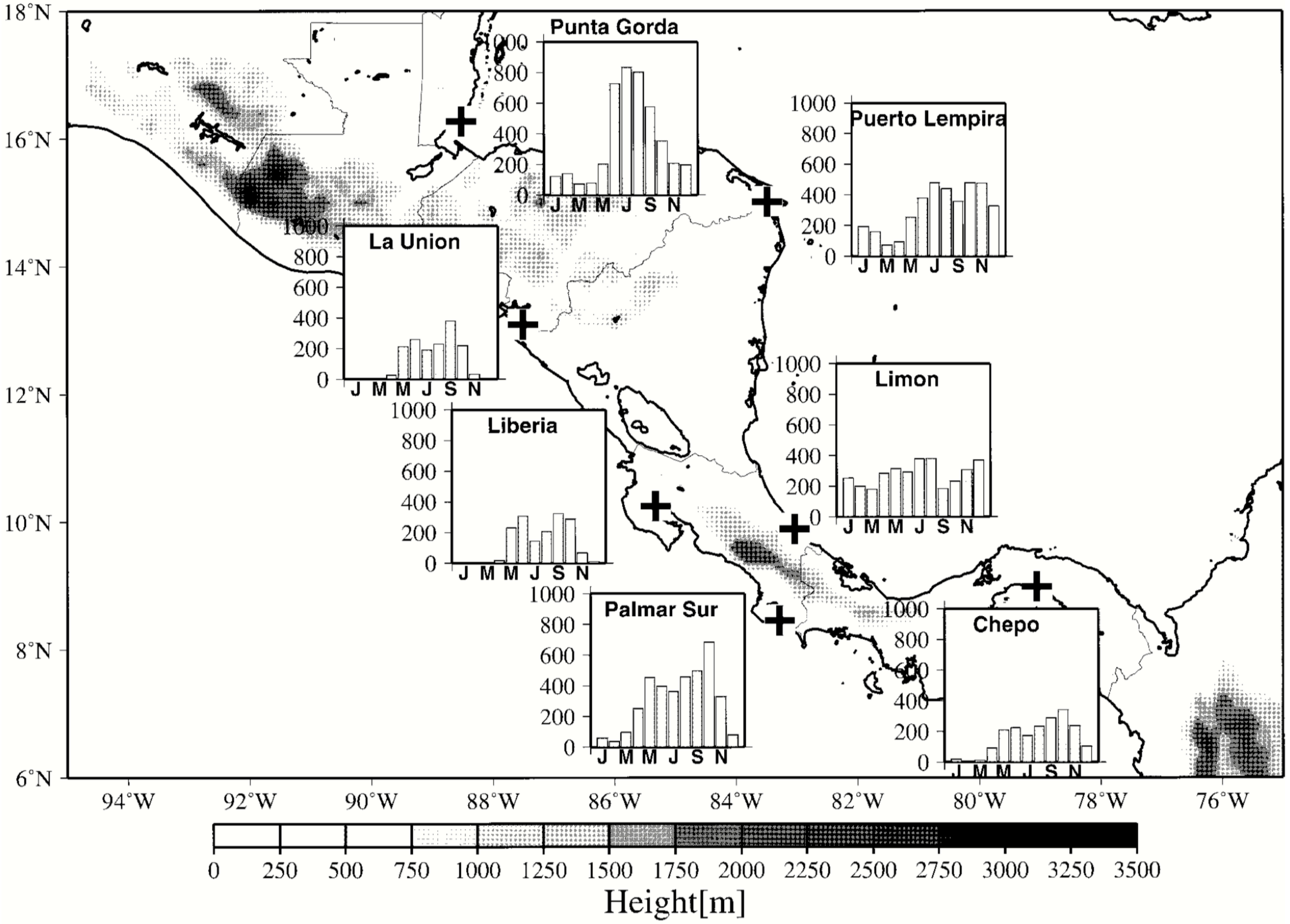


FIG. 9. Central American topography and monthly precipitation (mm) climatologies for stations along the Caribbean and the Pacific coast.

Magaña et al. (1999)

Temperature climatologies

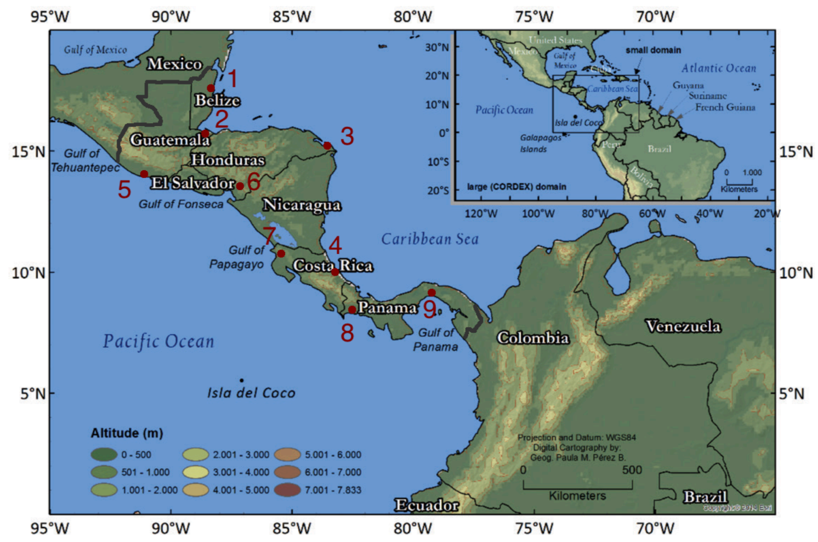
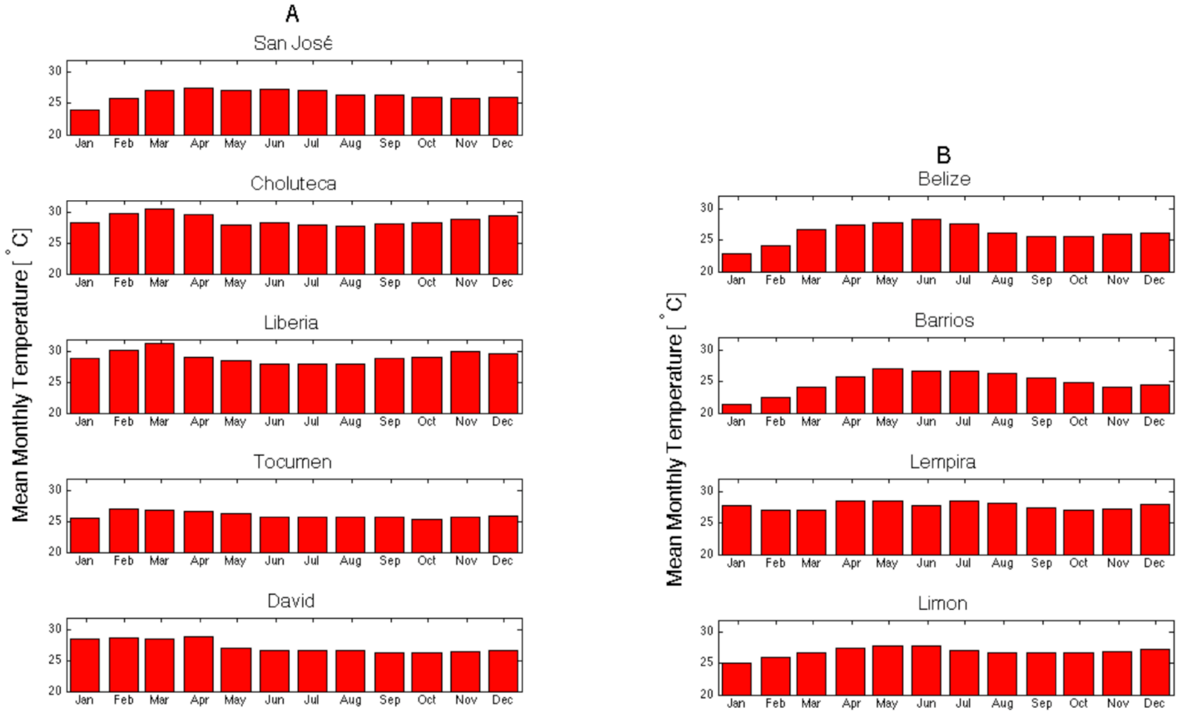


Table 2. Information about the meteorological stations and their dataset. The station numbers in the left column can be seen in figure 1. For each station the latitude, longitude and altitude can be found. The two right columns contain the information of missing data, in precipitation and temperature, for each station. The stations are situated at either the Pacific slope or Caribbean slope which is also marked with a P or a C, respectively.

Sation number (Station name/Slope)	Latitude	Longitude	Altitude [m]	Missing data precipitation [%]	Missing data temperature [%]
1 (Belize/C)	+17.533	-88.300	5	0.94	7.46
2 (Puerto Barrios/C)	+15.717	-88.600	1	1.26	22.25
3 (Lempira/C)	+15.217	-83.800	13	23.09	17.93
4 (Puerto Limon/C)	+9.967	-83.017	3	3.76	22.89
5 (San José/P)	+13.917	-90.817	2	8.94	0.85
6 (Choluteca/P)	+13.317	-87.150	48	21.39	16.73
7 (Liberia/P)	+10.600	-85.533	80	3.47	26.4
8 (David/P)	+8.400	-82.417	26	3.06	20.39
9 (Tocumen/P)	+9.050	-79.367	45	17.84	16.76



(a) The Pacific slope

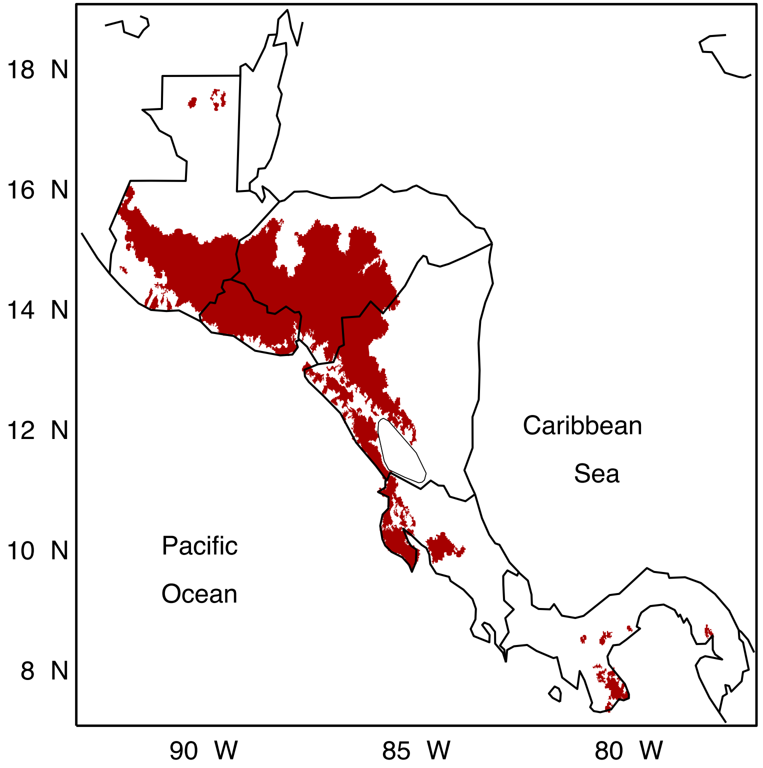
(b) The Caribbean slope

Figure 7. Monthly mean temperature [°C] for the 35 year period (1981-2015). The meteorological stations in each subfigure are in latitudinal order with the northernmost station's graph in the upper position.

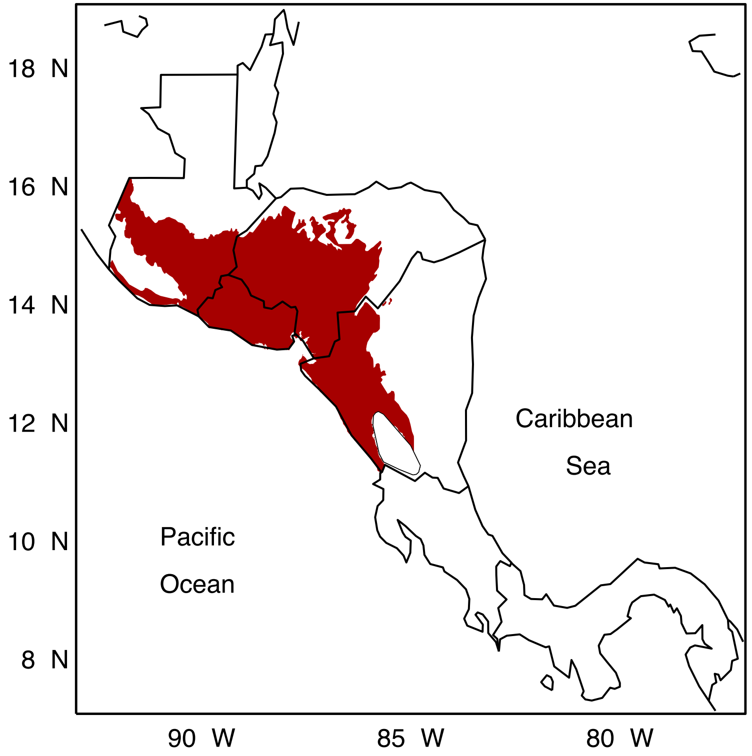
Sievert (2016)

Some delimitations of the Central America Dry Corridor (CADC)

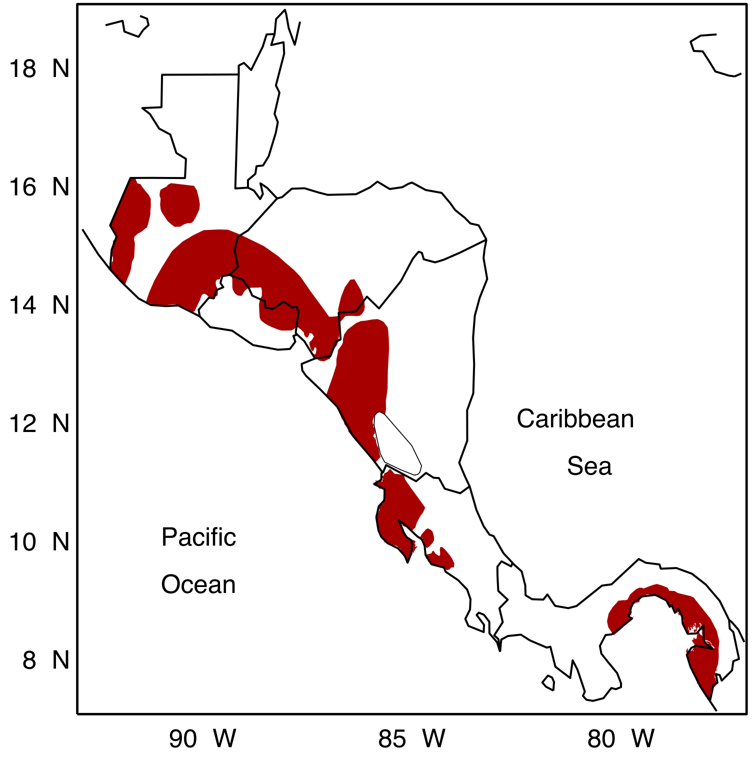
Central American Atlas* (2011)



FAO (2012)



Ramírez (2007)



* Atlas Centroamericano para la Gestión del Territorio (2011)

Geospatial data: Paula Marcela Pérez Briceño

A (non-exhaustive) list of climate-controlling processes in the Central American region

ITCZ, ENSO, Caribbean Low Level Jet and NASH

The Inter-tropical Convergence Zone (ITCZ)

DJF

JJA

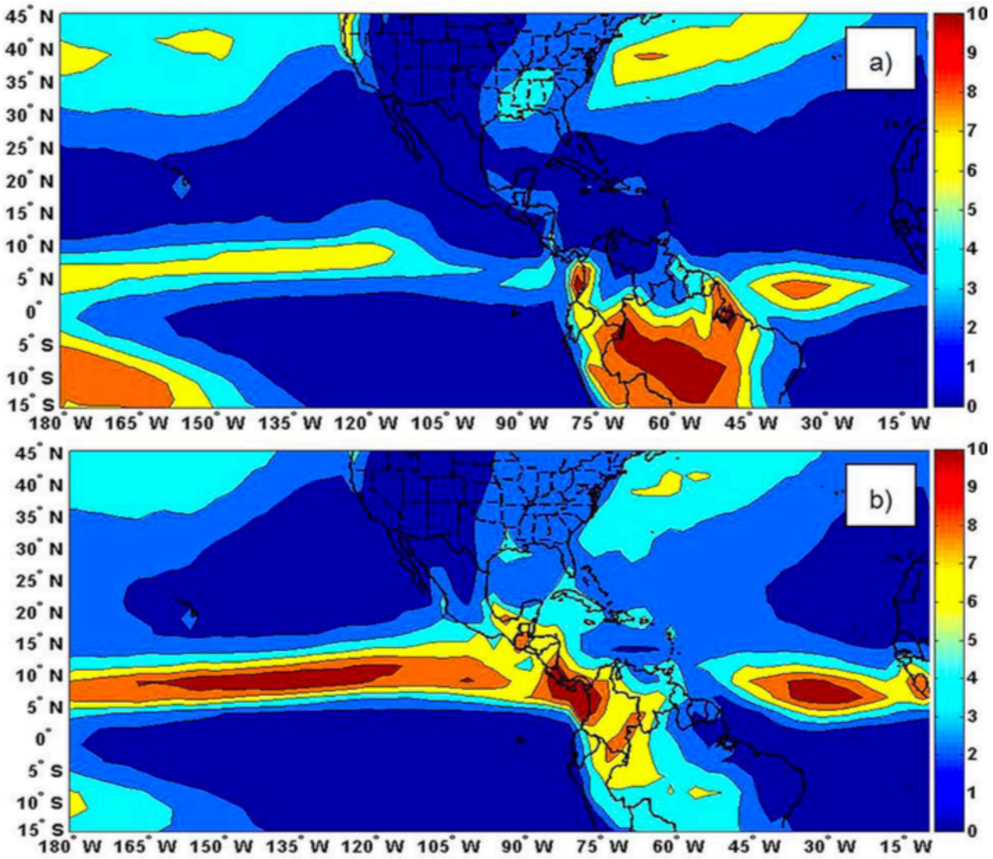


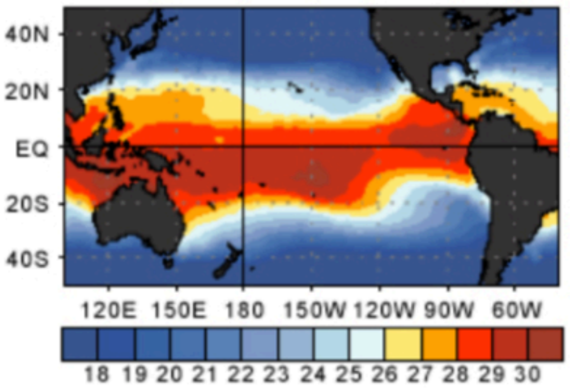
Figura 5 .Ubicación espacial de la ZCIT en el trimestre a) DEF y b) JJA, con datos de precipitación (mm/mes) del GPCP del periodo 1979-2012.

Quirós and Hidalgo (2016)

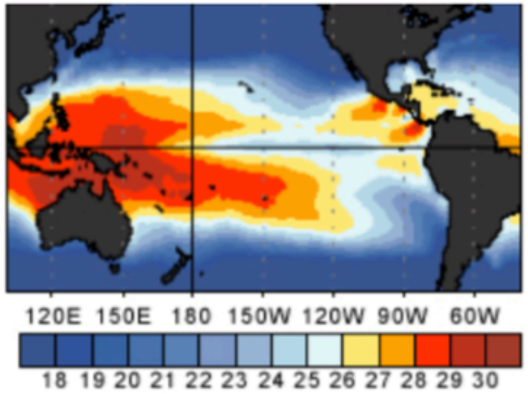
UNIVERSIDAD DE COSTA RICA

El Niño-Southern Oscillation (ENSO)

El Niño conditions Jan-Mar 1998



La Niña conditions Jan-Mar 1989



Sea Surface Temperature (°C)

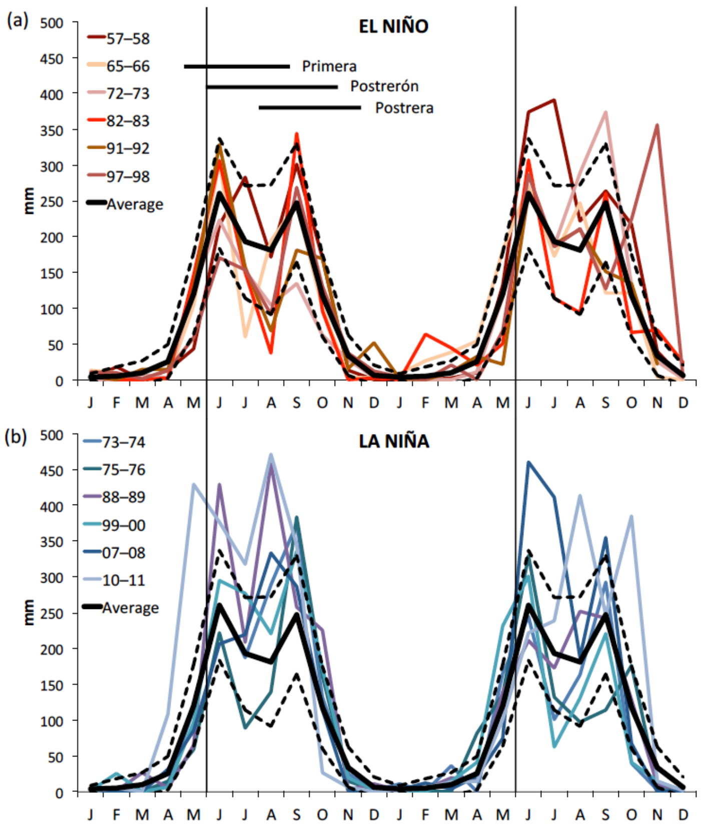


Figure 2. Average monthly precipitation for Guatemala City Observatory (INSIVUMEH) between 1960 and 1990 (black, panel **a**) compared to individual precipitation records for the six strongest El Niños (57–58, 65–66, 72–73, 82–83, 97–98) and (**b**) compared to the six strongest La Niñas (73–74, 75–76, 88–89, 99–00, 07–08, 10–11) of the 20th century in the Oceanic Niño Index (ONI; NOAA Climate Prediction Center; CPC). Vertical lines mark the usual start and end of an El Niño–Southern Oscillation (ENSO; May–June) year, peaking in boreal autumn and winter (Curtis, 2002). Horizontal lines indicate the three time frames of modern crop production in Central America (Arias et al., 2012). The first, second and third crop seasons are indicated by the terms "primera", "prostrerón" and "postrera" respectively. Dashed lines indicate 1 standard deviation with respect to the average monthly precipitation of the 1960–1990 period.

Guevara-Morua et al. (2018)

The Caribbean Low Level Jet (CLLJ)

Amador (1998 Tópicos Met. y Ocean.; 2008 Ann. N.Y. Acad. Sci.)

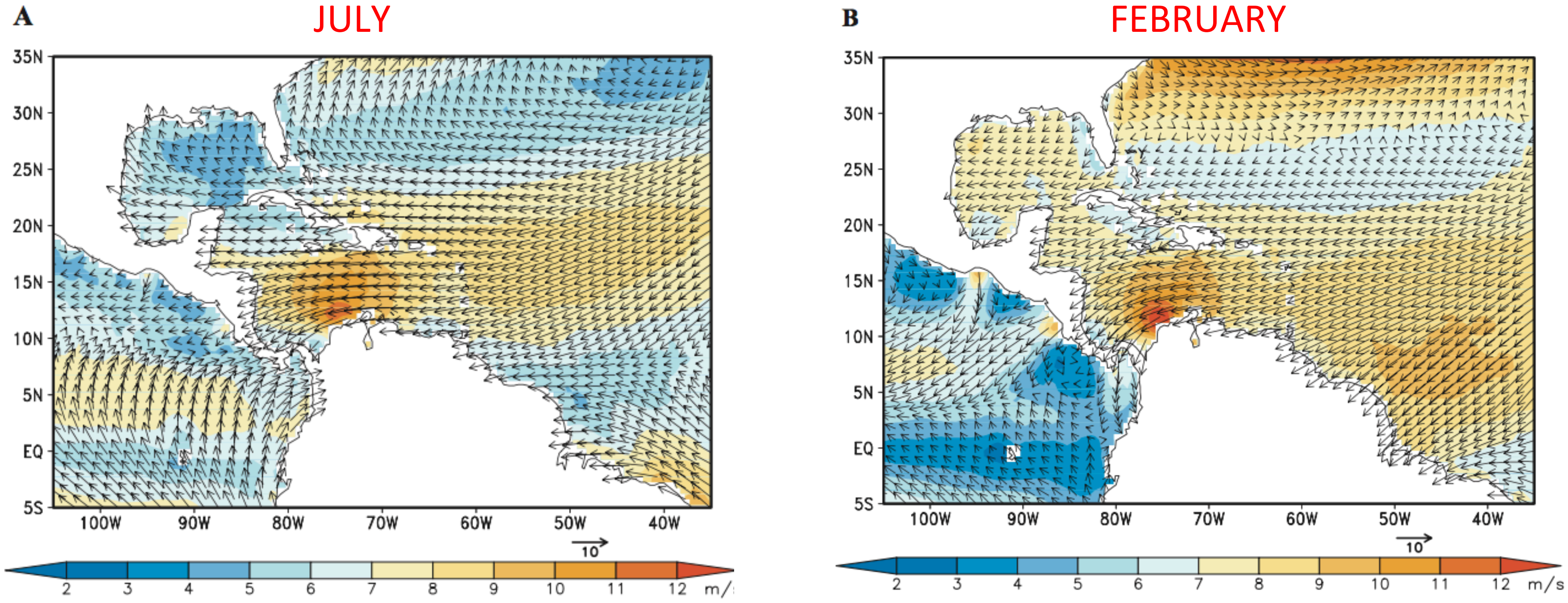
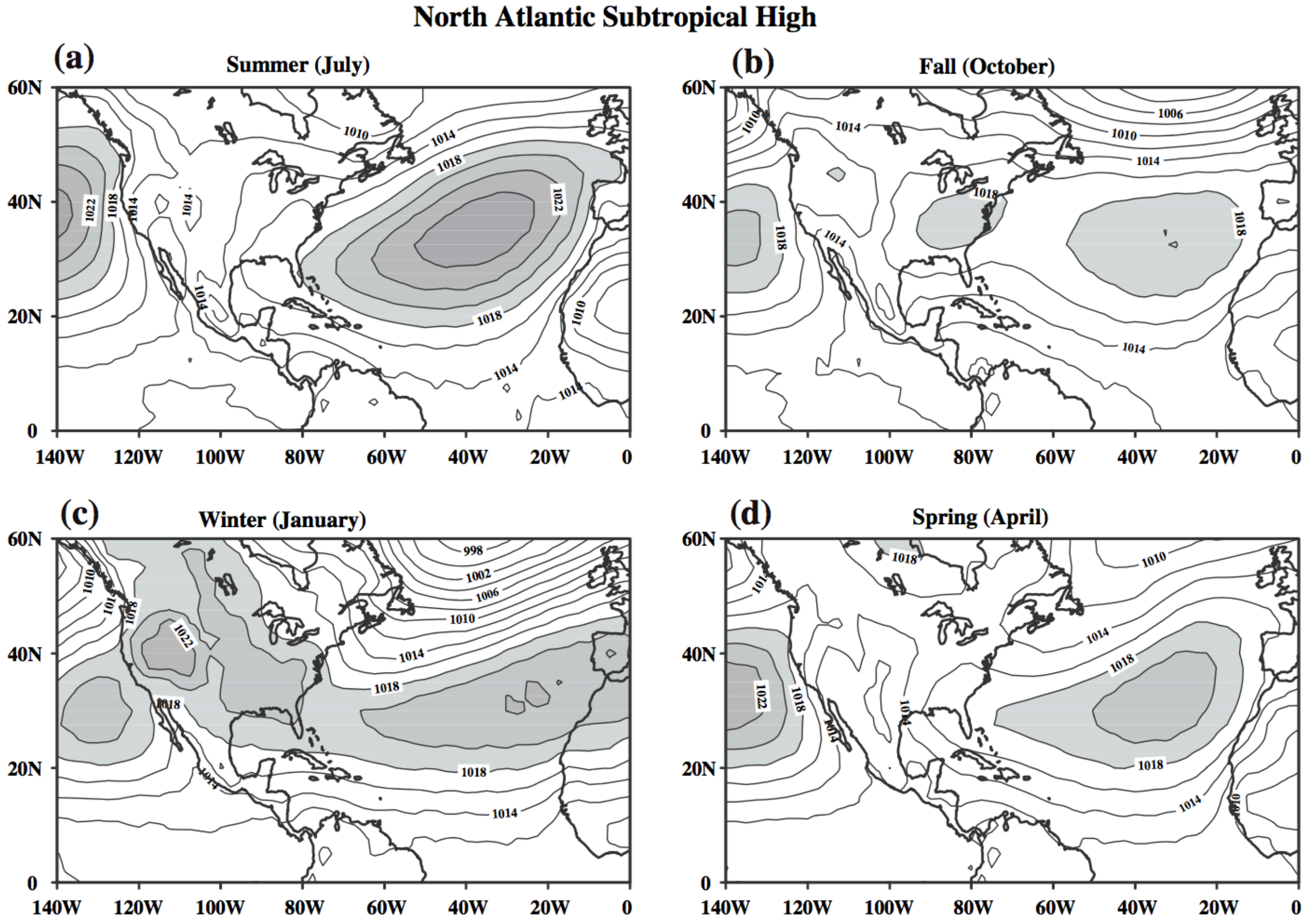


Figure 8. Mean QuikSCAT winds (m s^{-1}) for **(A)** July and **(B)** February for the period 2000–2007. (In color in *Annals* online.)

Amador (2008)

The North Atlantic Subtropical High (NASH)

Fig. 4 Sea level pressure (hPa) in the **a** summer (July), **b** fall (October), **c** winter (January), and **d** spring (April) showing the seasonal variations of the North Atlantic Subtropical High (NASH). Sea level pressure larger than 1,018 hPa is *shaded*



Wang (2007)

(Hydro)climate variability

Precipitation, temperature and drought trends

Flooding associated with ENSO

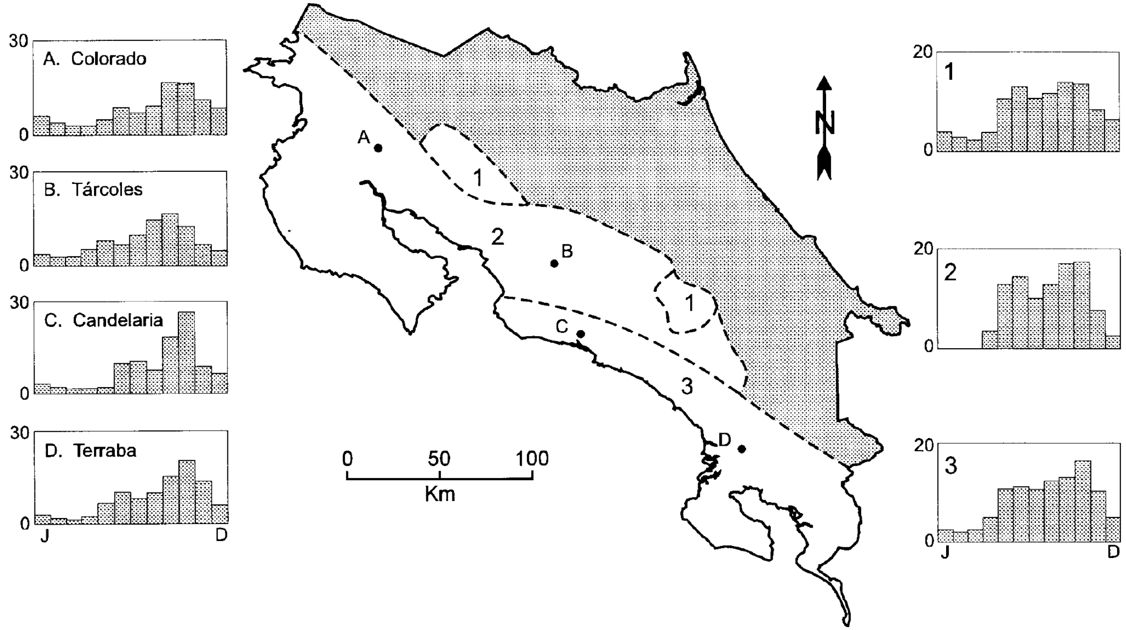


Figure 2. Mean monthly discharges as a percentage of annual discharge on the four study basins, and equivalent monthly percentages of rainfall within the three precipitation regions drained by the basins

Table II. Estimates of L-moments, parameters of the Generalized Extreme Value distribution and the ten-year return period annual flood for each basin using the entire sample and subsamples divided upon the basis of ENSO conditions

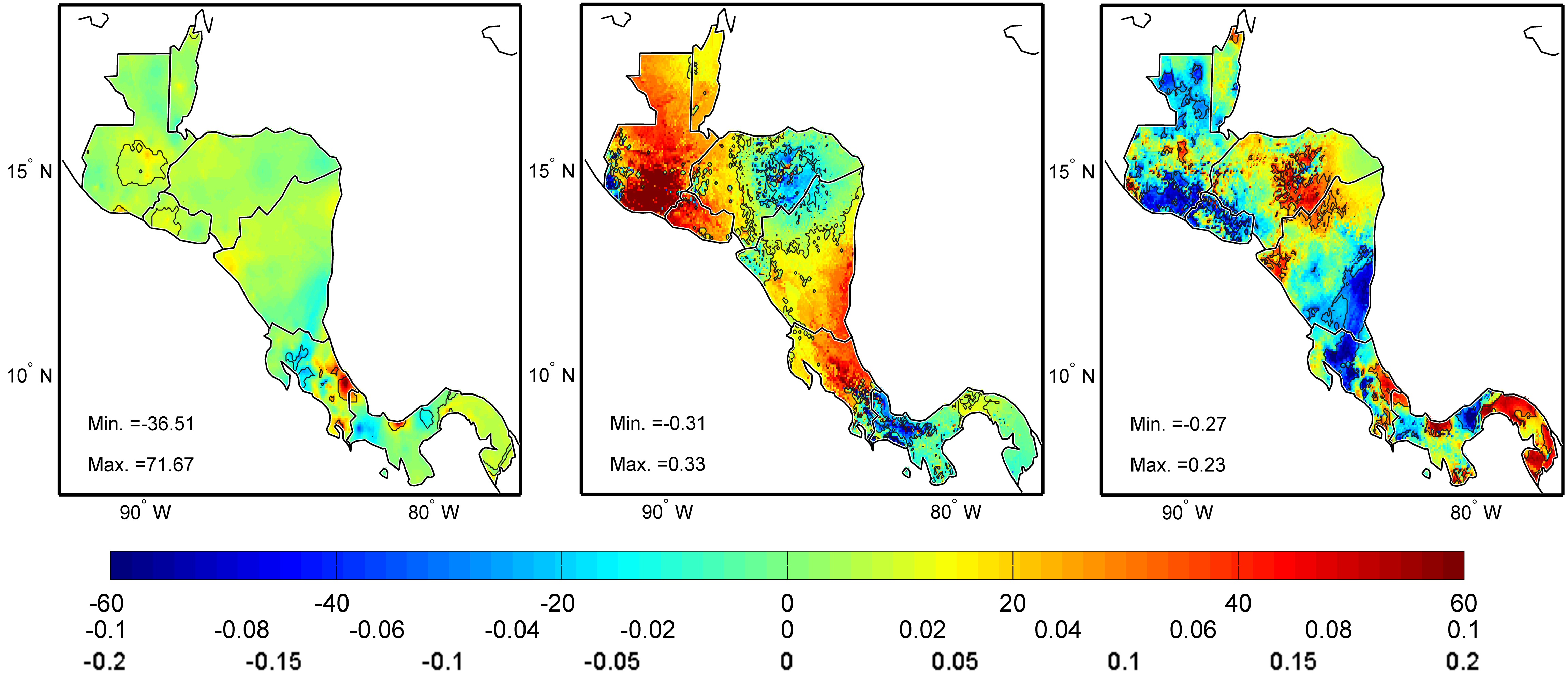
			L-Moments			GEV			
Basin	Class	Years	L-Mean	L-Cv	L-Skew	ξ	α	κ	Q_{10} ($m^3 s^{-1}$)
Colorado	All	40	61·4	0·523	0·557	29·3	22·1	−0·492	120·4
	Cold	7	67·4	0·279	0·057	57·5	28·5	+0·288	104·7
	Warm	9	31·0	0·431	0·281	20·8	16·4	−0·050	59·7
	Other	24	71·1	0·586	0·663	30·4	23·0	−0·582	137·4
Tárcoles	All	19	480·5	0·371	0·502	309·2	146·0	−0·389	834·4
	Cold	5	608·8	0·354	0·296	477·4	270·6	+0·101	1022·0
	Warm	14	245·8	0·110	0·734	233·6	36·1	+0·309	292·2
	Other	10	510·3	0·397	0·561	326·3	160·9	−0·376	895·6
Candelaria	All	29	270·0	0·318	0·439	187·2	78·0	−0·388	450·1
	Cold	6	397·8	0·420	0·454	270·1	173·5	−0·140	729·1
	Warm	7	185·3	0·178	0·254	163·5	44·0	+0·089	253·2
	Other	16	259·1	0·287	0·364	192·7	79·7	−0·210	421·6
Terraba	All	30	1966·8	0·305	0·414	1392·0	572·3	−0·309	3253·1
	Cold	6	2466·7	0·236	0·305	2081·4	738·7	+0·059	3637·5
	Warm	7	1409·4	0·215	0·615	1152·1	256·5	−0·309	1985·7
	Other	17	2019·9	0·338	0·481	1373·4	589·2	−0·355	3403·3

Waylen and Laporte (1999)

Trends in annual averages/totals (1970-1999)

Hidalgo et al. (2017)

PRECIPITATION **TEMPERATURE** **PALMER HYD. DROUGHT INDEX**



Modelled runoff historical changes in Northern and Southern Central America (1948-2012)

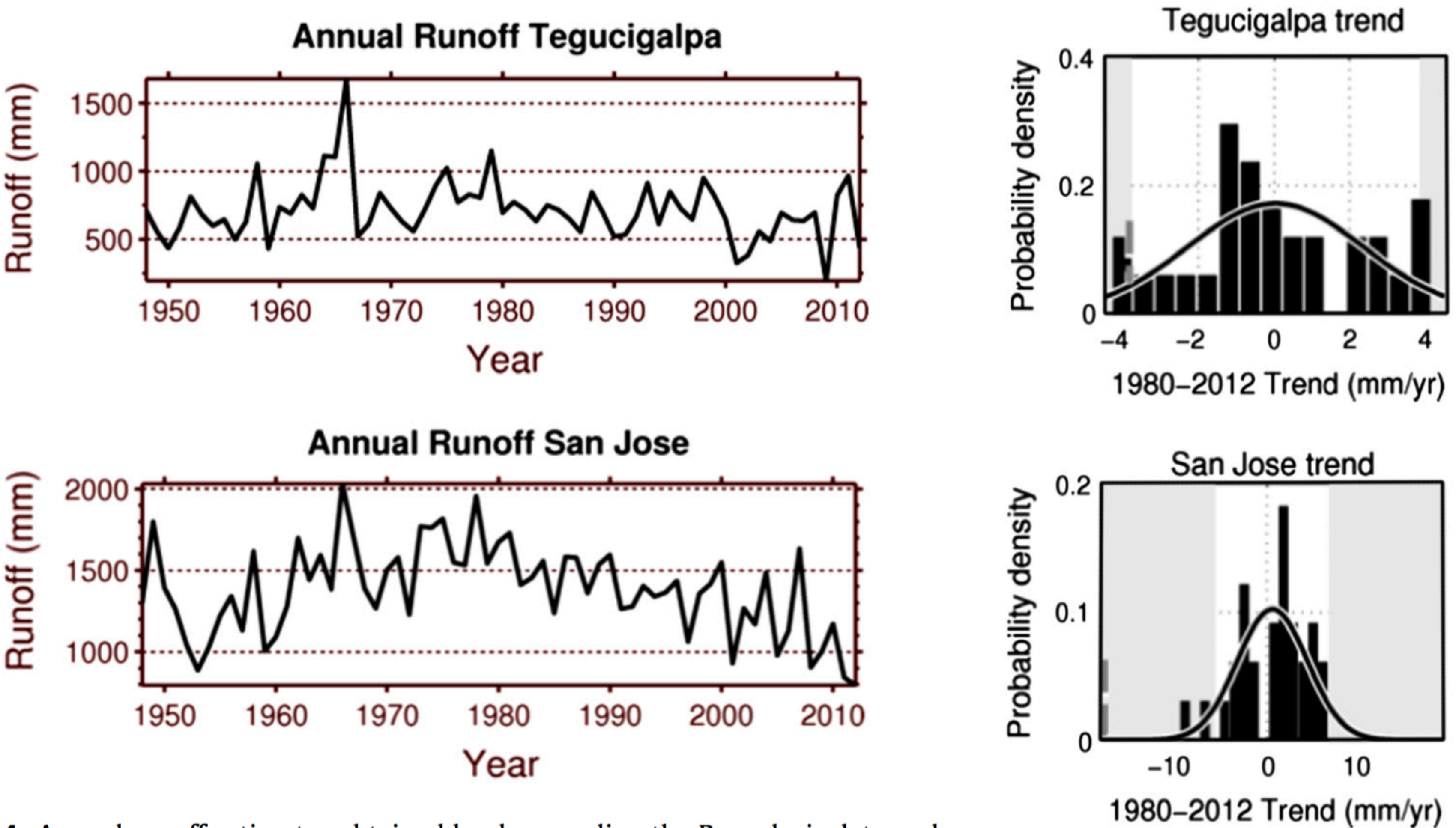


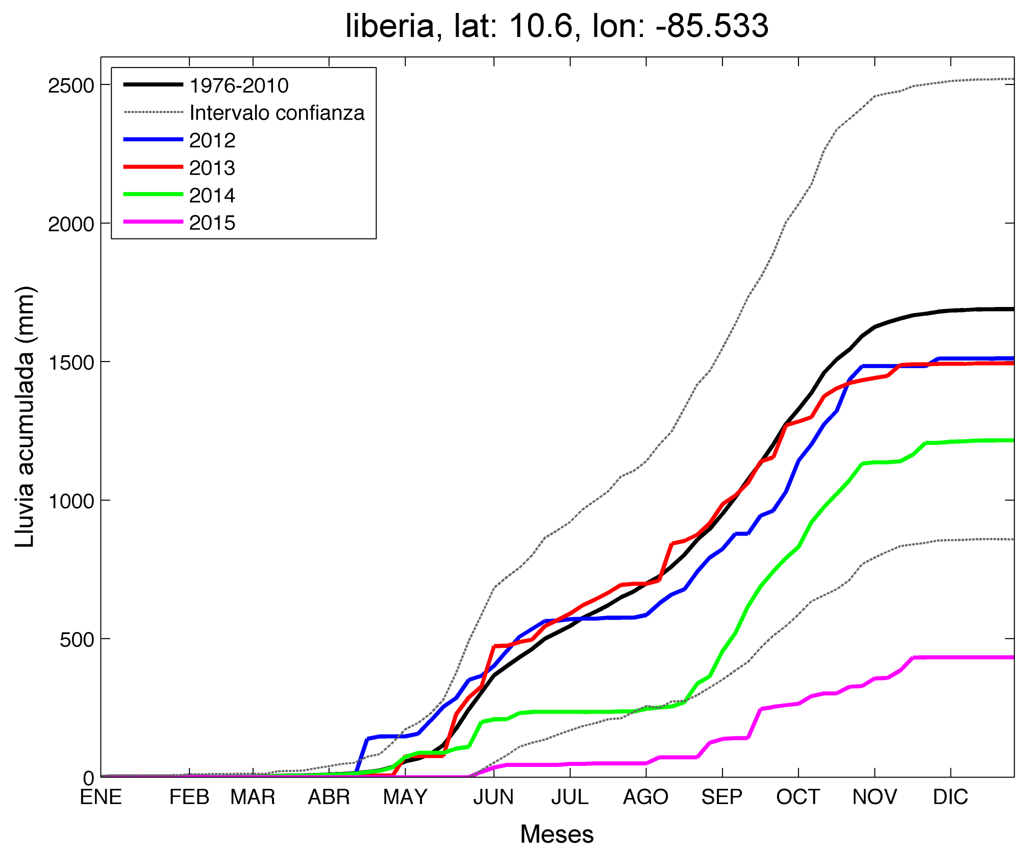
Fig. 14. Annual runoff estimates obtained by downscaling the Reanalysis data and ran them through VIC from 1948 to 2012 for two locations.

Hidalgo et al. (2013)

UNIVERSIDAD DE COSTA RICA

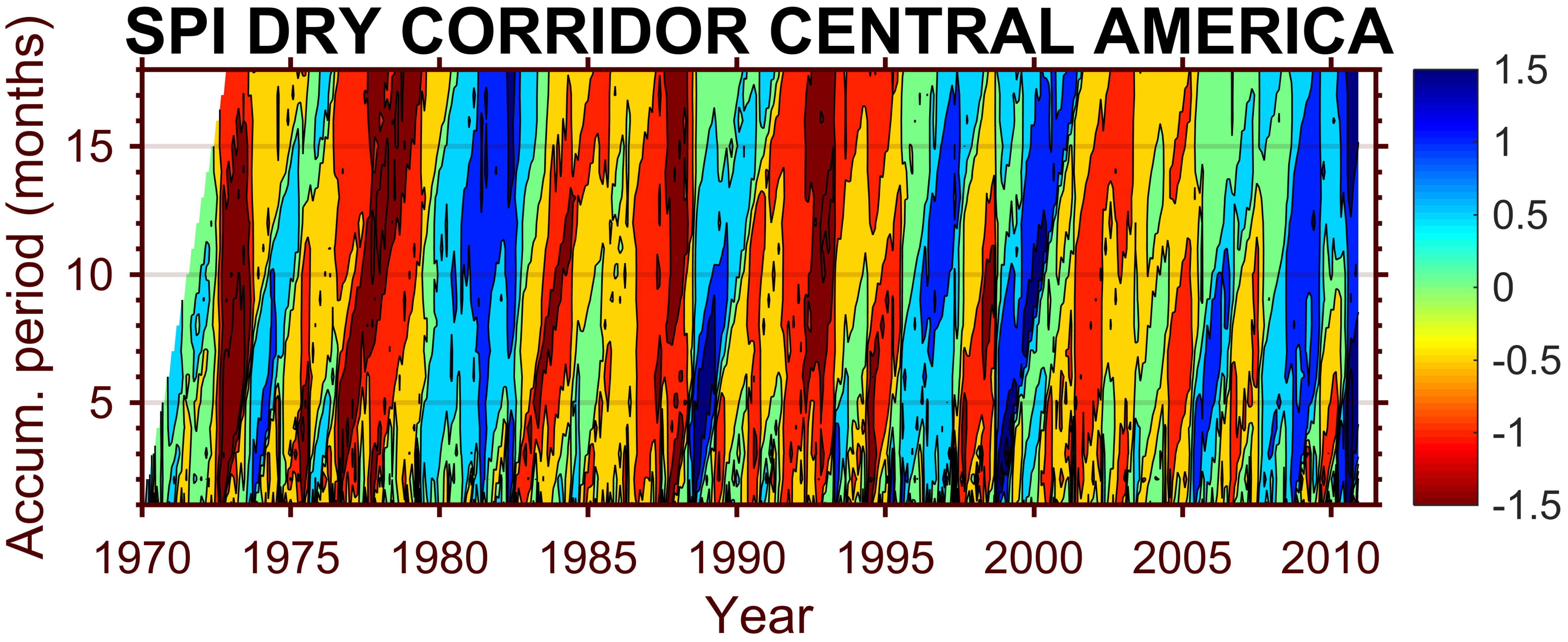
Liberia, Guanacaste, northwestern Costa Rica (1976-2015)

Hidalgo et al. (2016, Ojo al Clima)



Standardized Precipitation Index in the CADC from 1970 to 2010

Hidalgo et al. (submitted, Climate Dynamics).



Time-series of several climatic indexes in the CADC

Hidalgo et al. (submitted Climate Dynamics).

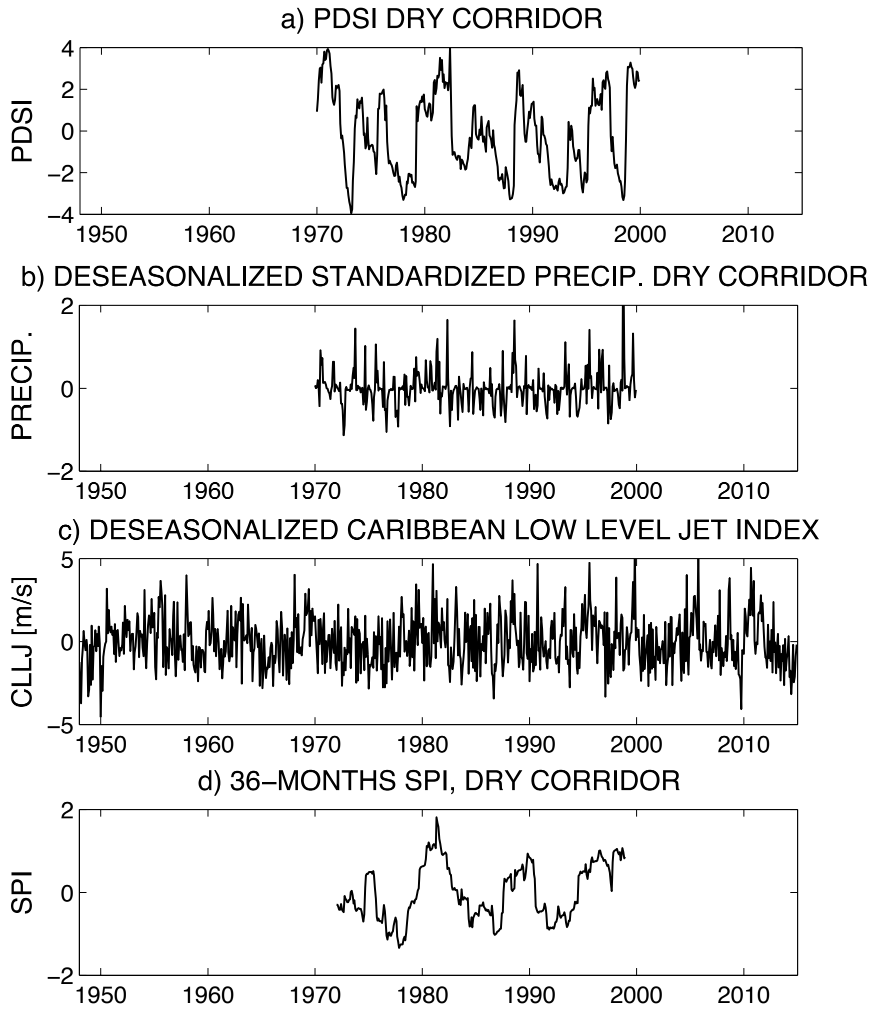


Table 2. Percentage of total spectral power contained in the 6 to 13 year periodicity band.

Time-series	**Percentage in 6-13 year band**
Monthly PDSI	30.0 %
Monthly deseasonalized Prec CADC	5.8 %
Monthly deseasonalized CLLJ	6.7 %
Monthly SPI, 36 month time-scale	76.6 %

(Hydro)climate change

Projections

Changes in streamflow (%) during climate change scenarios

16 climate models each using two emissions scenarios (lower B1 and mid-high A2) and two horizons: during the middle (2040–2069) and end (2070–2099) of the 21st century.

BCSD downscaling

A land surface model was applied to investigate hydrologic impacts to two major hydropower reservoirs.

By 2070–2099 the median warming relative to 1961–1990 was 1.9°C and 3.4°C under B1 and A2 emissions, respectively.

For the same periods, the models project median precipitation decreases of 5.0% (B1) and 10.4% (A2).
Median changes by 2070–2099 in reservoir inflow were 13% (B1) and 24% (A2)
Frequency of low flow years increases, implying decreases in firm hydropower capacity of 33% to 53% by 2070–2099.

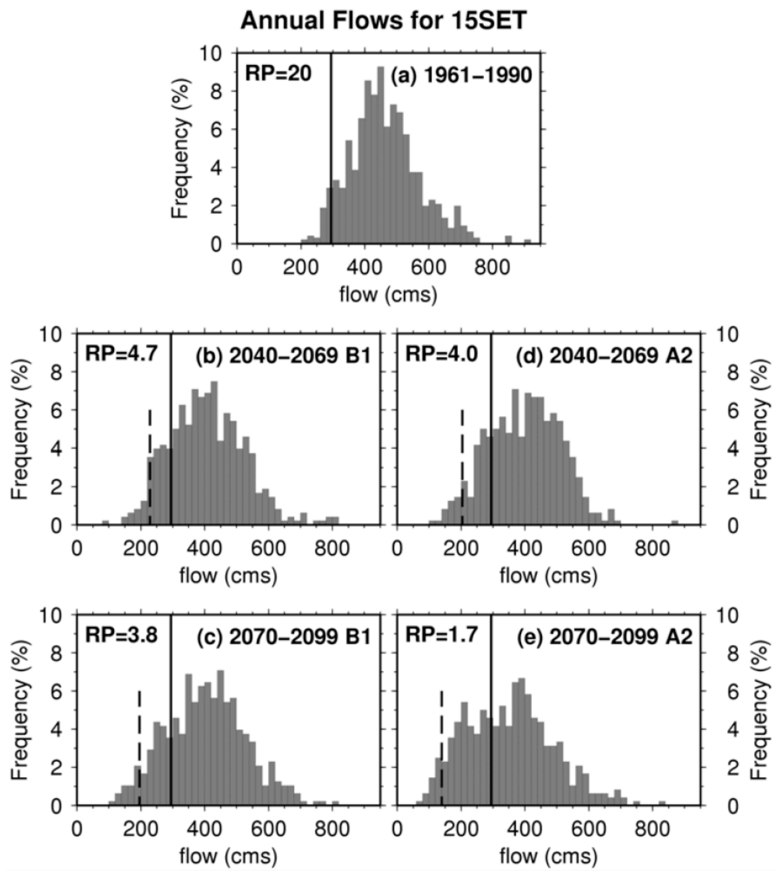


Fig. 7. Histograms of Annual Inflows in m^3/s (cms) into 15 Setiembre for the 1961–1990 base period and two future periods. The solid vertical line indicates low flow with a return period (RP) of 20-years for 1961–1990, which is repeated on all panels. The vertical dashed lines in panels b-d indicate the RP=20 value for each emissions scenario and future time period. The RP values in the upper left corner of panels b-d indicate the return period for flows occuring below the climatological RP=20 value for 1961–1990.

Maurer et al. (1999)

UNIVERSIDAD DE COSTA RICA

Changes in runoff (%) at the end of the century

Mapped Atmosphere Plant Soil System (MAPSS)

136 runs generated with 23 general circulation models (GCMs)

Downscaling: delta method

LAI is likely to decrease over 77%–89% of the region, depending on climate scenario groups,showing that potential vegetation will likely shift from humid to dry types.

Runoff will decrease across the region even in areas where precipitation increases (even under increased water use efficiency), as temperature change will increase evapotranspiration.

Imbach et al. (2012)

2012 IMBACH ET AL.

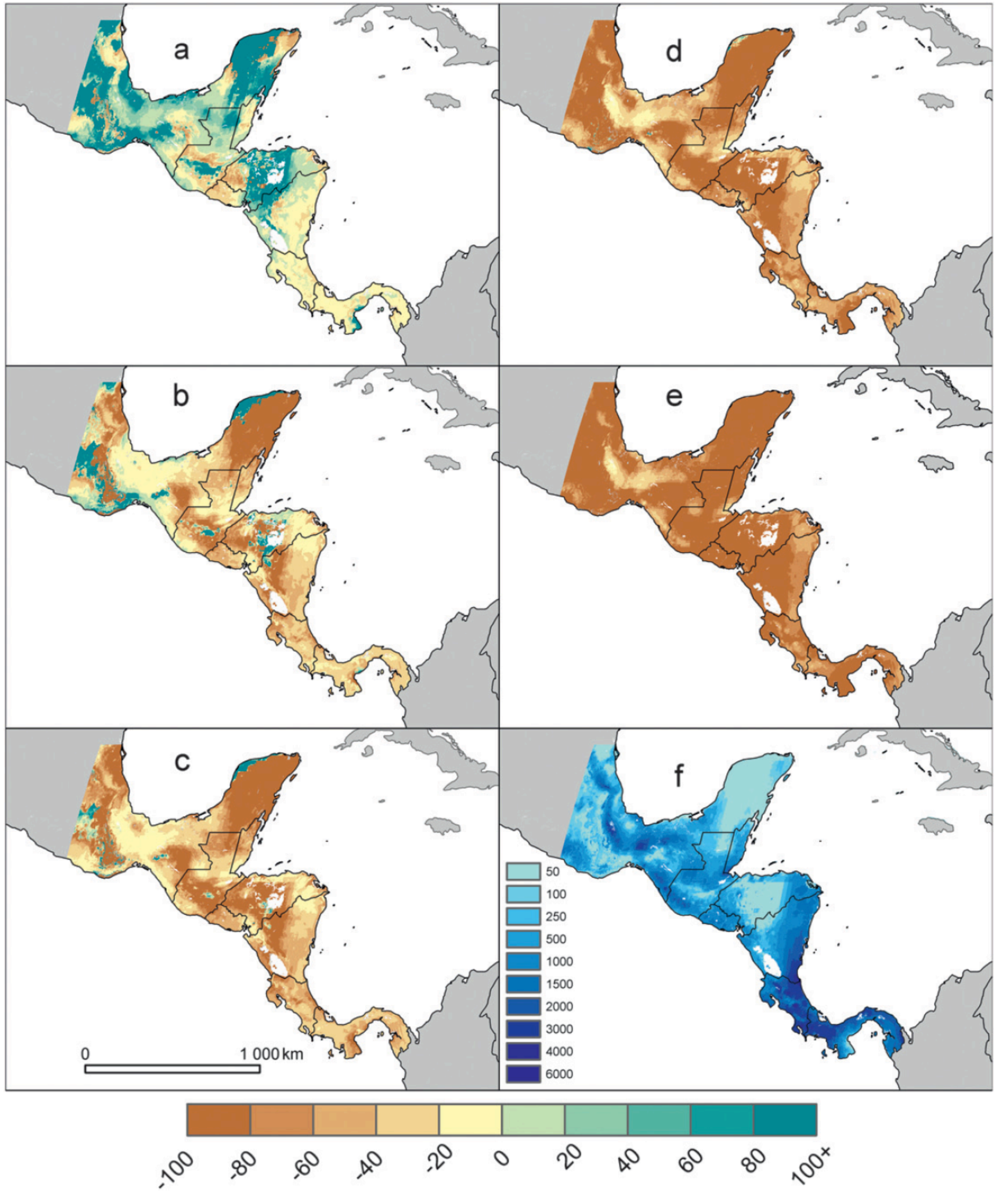


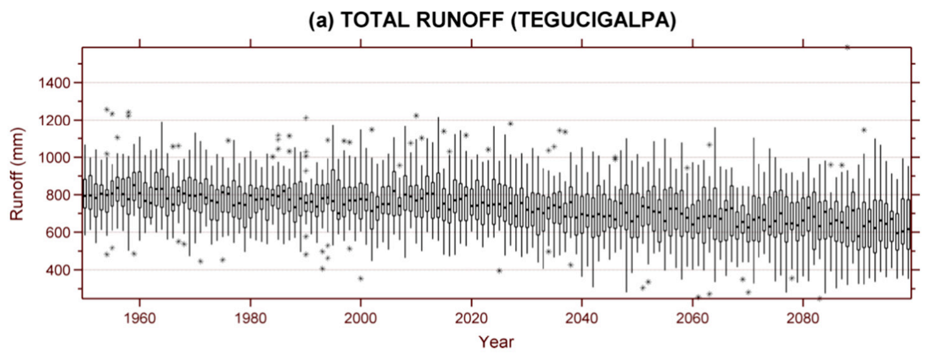
FIG. 3. Change in annual runoff (%) for the (a) maximum, (b) 75th percentile values, (c) 50th percentile values, (d) 25th percentile values, and (e) minimum of the A2 ensemble scenarios compared to (f) the reference period (1950–2000; mm).

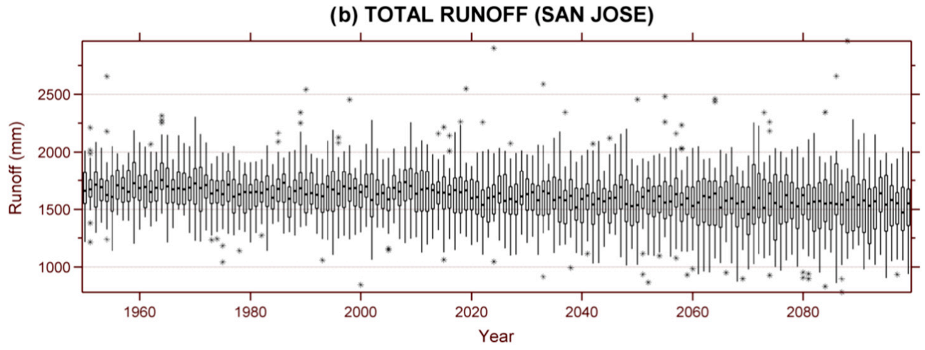
Changes in runoff (%) at the end of the century

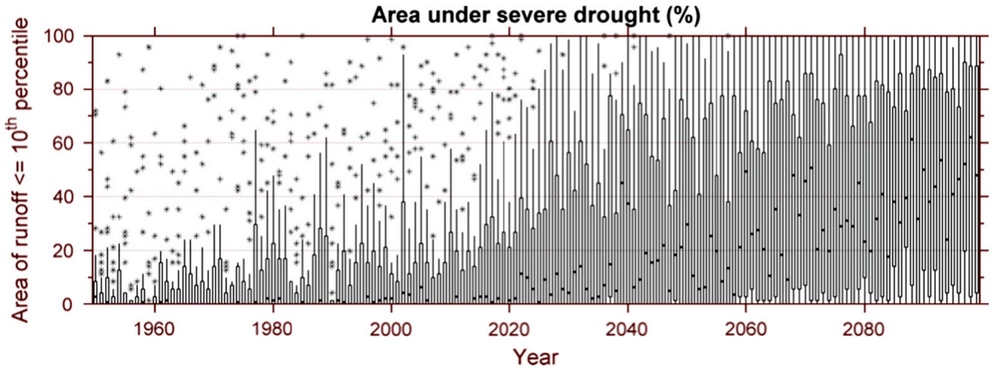
Runoff climate change projections for the 21st century were calculated from a suite of 30 General Circulation Model (GCM) simulations for the A1B emission scenario in a 0.5^o x 0.5^o grid over Central America.

Variable Infiltration Capacity Model.

BCSD downscaling

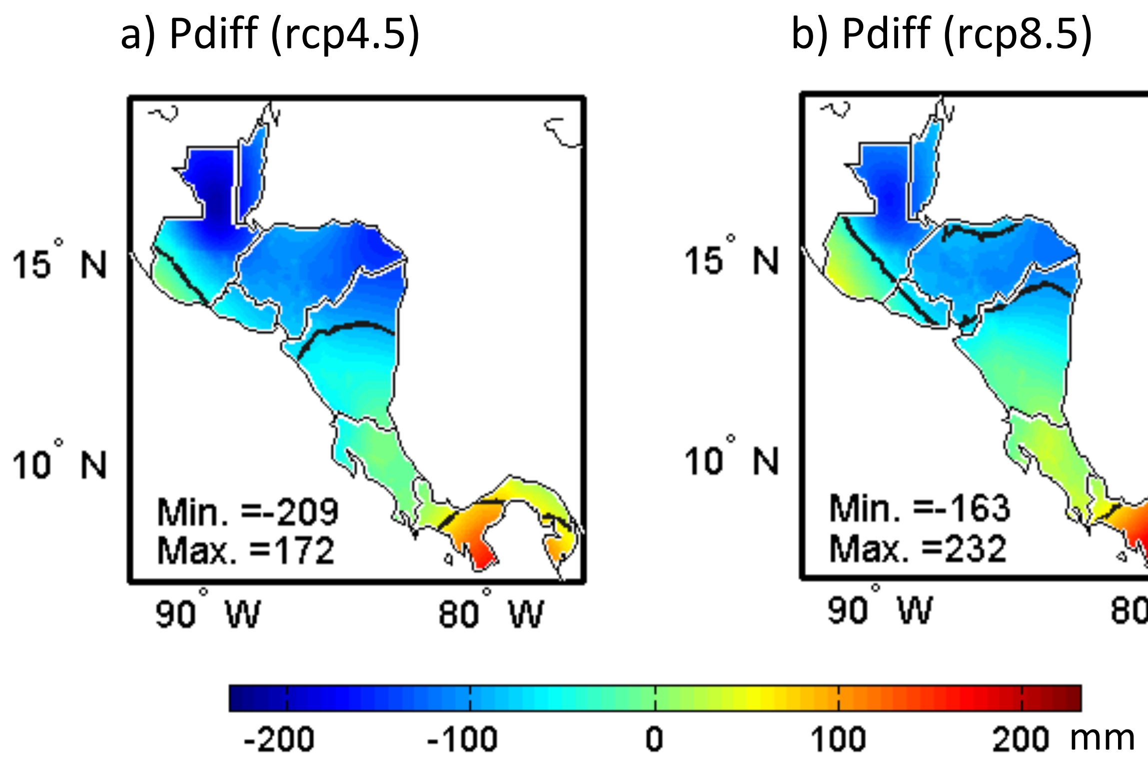






Hidalgo et al. (2013)

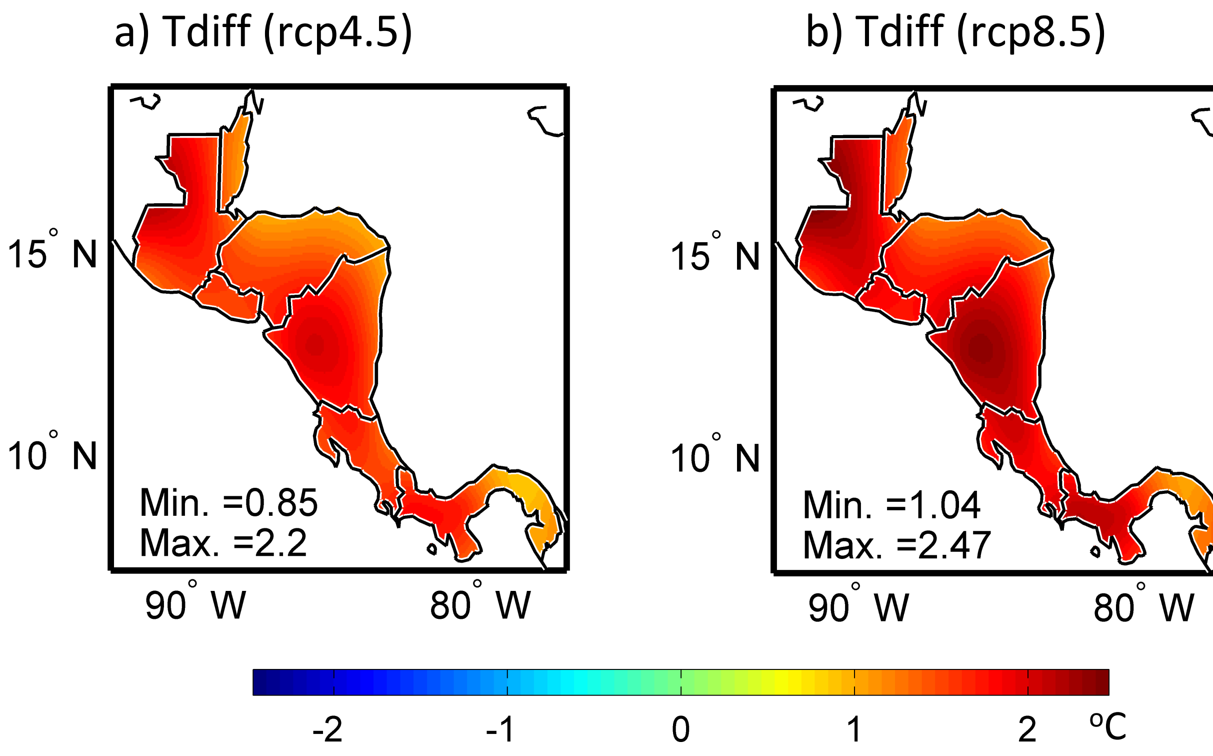
Difference between future scenario (2029-2049) minus historical scenario (1979-1999) in annual precipitation



Hidalgo et al. (2017)

UNIVERSIDAD DE COSTA RICA

Difference between future scenario (2029-2049) minus historical scenario (1979-1999) in annual temperature



Hidalgo et al. (2017)

Changes in Precipitation, Temperature and MSD strength for 2021-2050

Eta- model (8-km), HadGEM2-ES GCM
RCP4.5 scenario

Precipitation is generally reduced, in particular during the JJA and SON, the rainy season.

Warming is expected over the region, but stronger in the northern portion of the continent

The Mid-Summer Drought may develop in regions that do not occur during the baseline period, and where it occurs the strength may increase in the
future scenario.

The Caribbean Low-Level Jet shows little change in the future.

Imbach et al. (2018)

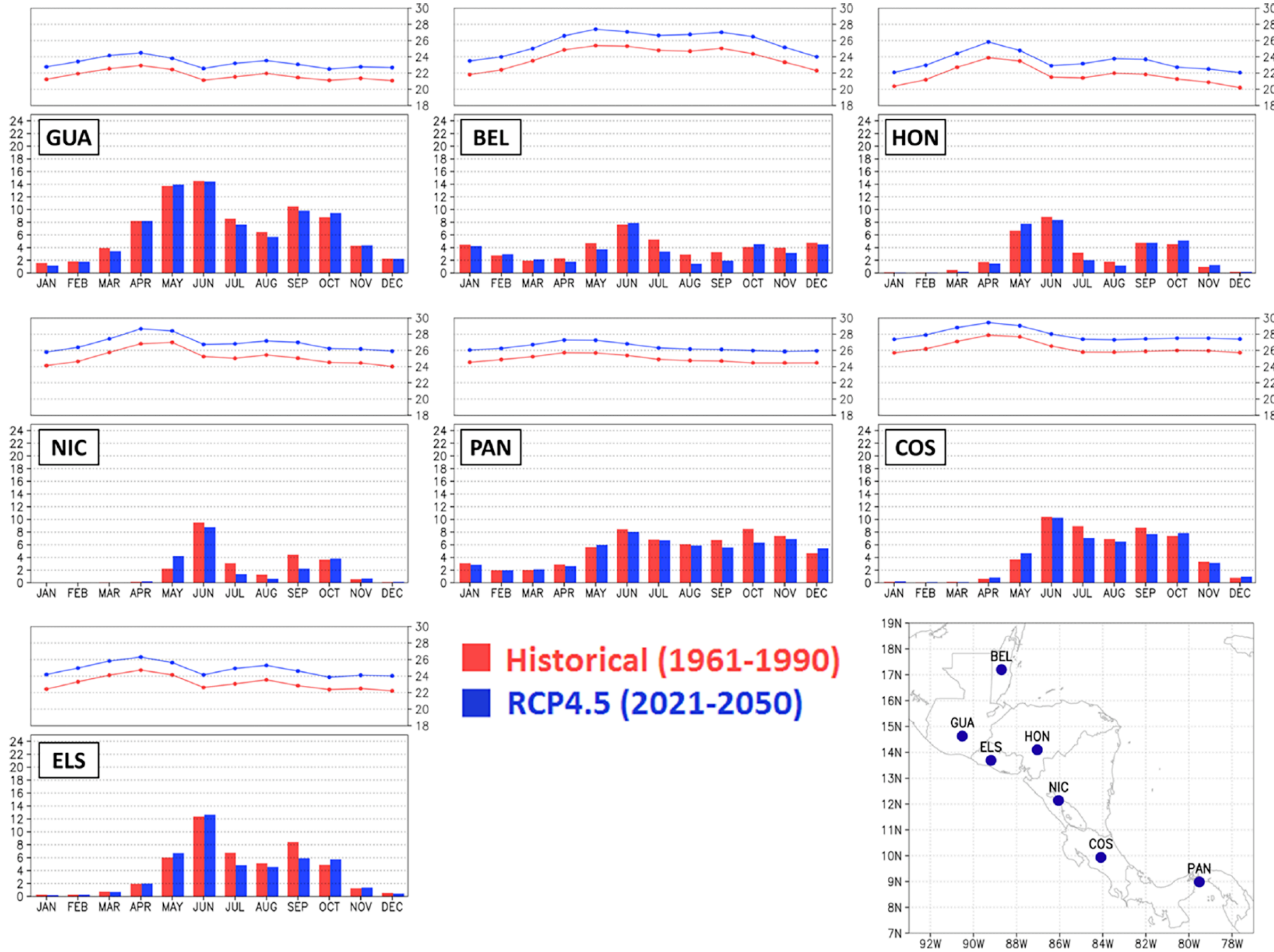


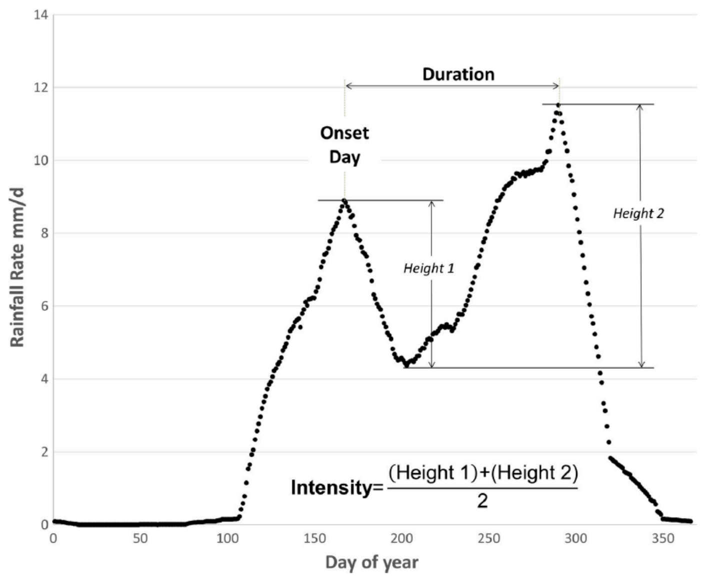
Fig 10. Annual cycle in precipitation (mm/day) and 2-metre temperature (°C) for the capital cities in Central America. Historical period (in red), 1961–1990, and future period (in blue), 2021–2050, under RCP4.5 scenario. The three initial letters of the country of the respective capital city identify each box: Guatemala (GUA), Belize (BEL), Honduras (HON), Nicaragua (NIC), Panama (PAN), Costa Rica (COS), and El Salvador (ELS).

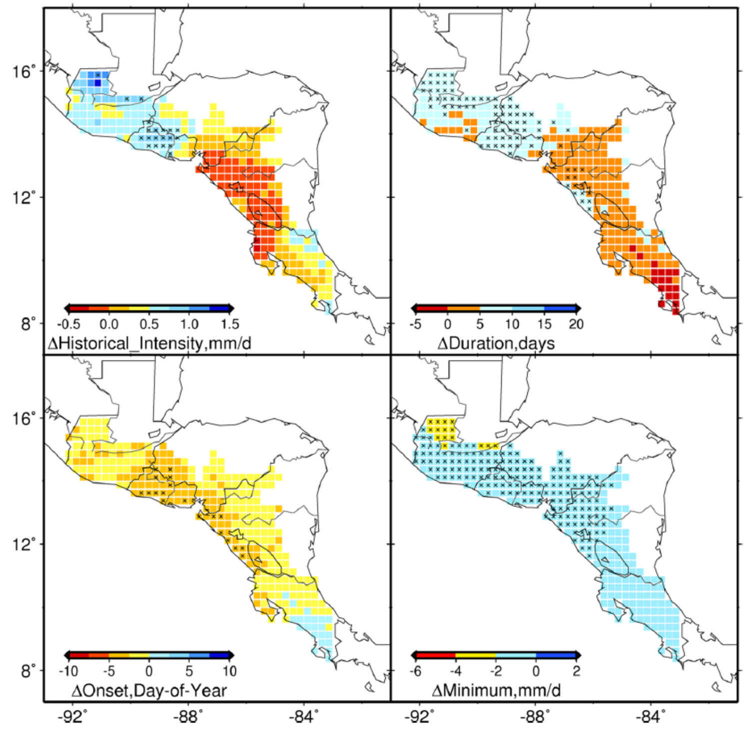
Changes in MSD characteristics at the end of the century

BCSD downscaling.

15 GCMS. RCP4.5 and RCP8.5

The most significant changes are for the duration, which is projected to increase by an average of over a week, and the MSD minimum precipitation, which is projected to decrease by an average of over 26%,





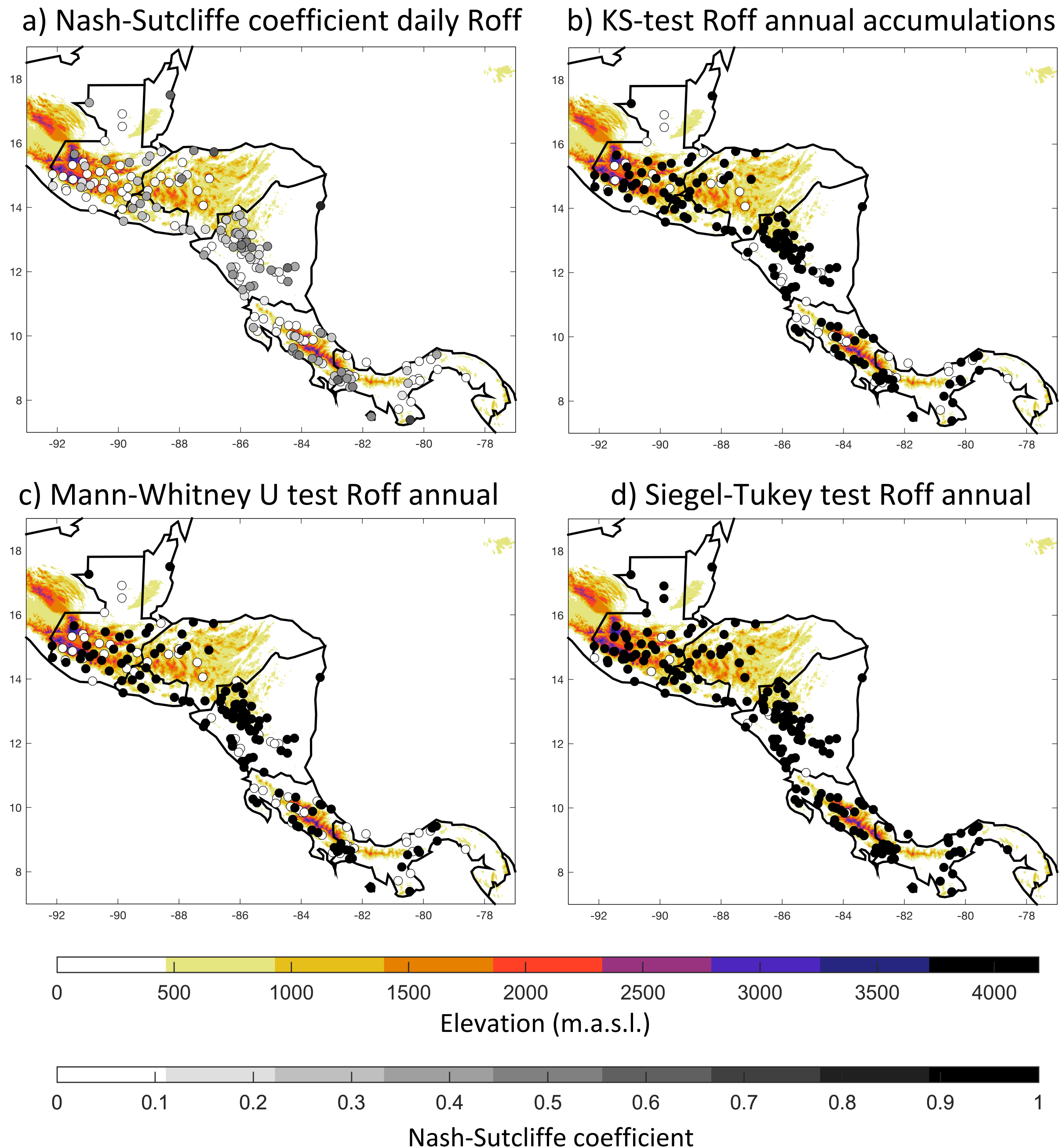
Maurer et al. (2018)

UNIVERSIDAD DE COSTA RICA

Validation of Localized Constructed Analogs (LOCA) downscaling

Figure 4. (a) Nash-Sutcliffe coefficient for daily runoff (Roff) by running the hydrological model VIC using as input the LOCA downscaling approach versus observed data. (b,c,d) Results of statistical tests of the median P annual. For b,c,d a filled black circle means that the test implies that the distributions, medians or the variability is equal at the p=0.05 level.

Hidalgo et al. (in preparation)



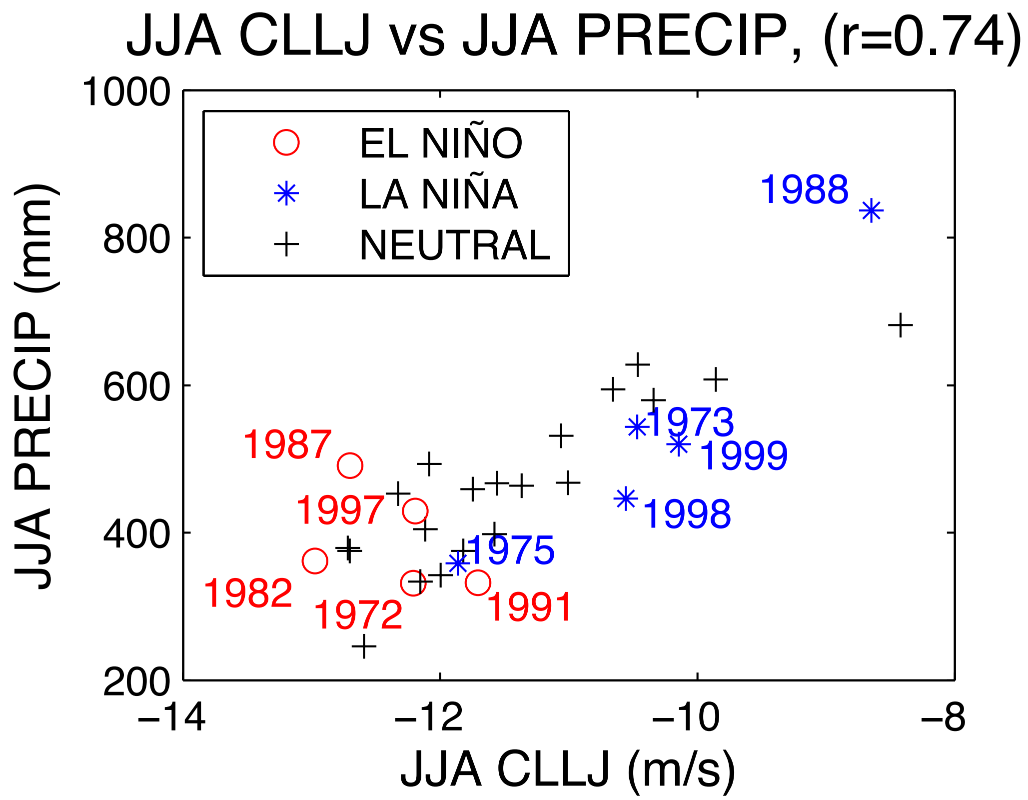

Thank you!

What controls severe and sustained droughts in the Central America Dry Corridor?

Relationships between precipitation, and CLLJ/ENSO

Relationship between the Caribbean Low Level Jet (CLLJ), ENSO and Precipitation in the CADC

Hidalgo et al. (in preparation)



Many studies (Magaña et al. 1999; Wang 2007; Muñoz et al. 2008; Whyte et al. 2008; Cook and Vizy 2010; Hidalgo et al. 2015; 2016; Durán-Quesada et al. 2016) have found significant correlations during boreal summer months between the strength of the Caribbean Low Level Jet or CLLJ (Amador 1998; 2008) and precipitation in the Pacific slope of Central America (including the CADC).

Filtered (low-pass) versions of time-series

Hidalgo et al. (in preparation).

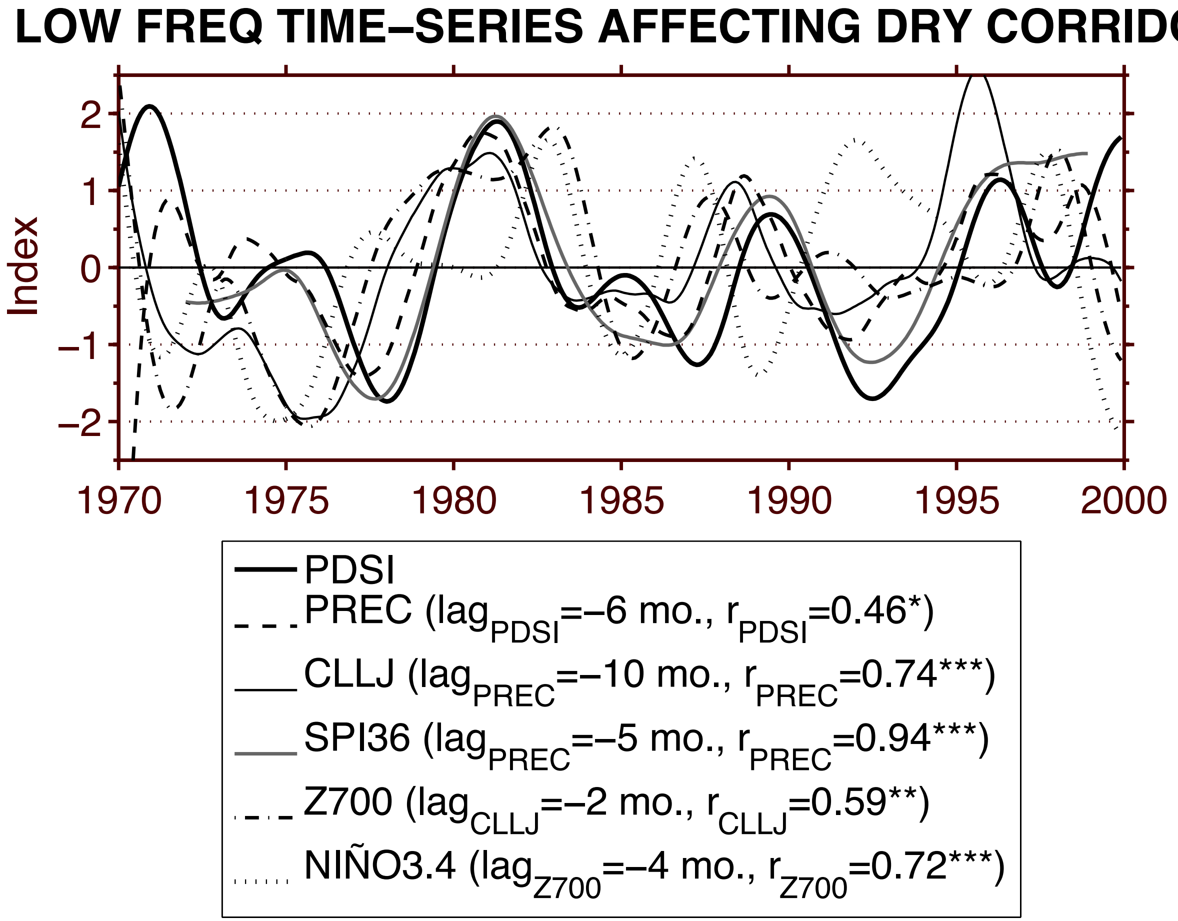


Figure 11. Standardized low-pass filtered data of time-series used in this study. The strongest correlations and their lags are included. Significant correlations are depicted with * (90% confidence), ** (95% confidence) and *** (99% confidence). Significance was established using Monte Carlo simulations of 10,000 realizations.