Las sequías climáticas: patrones de cambio y escenarios futuros

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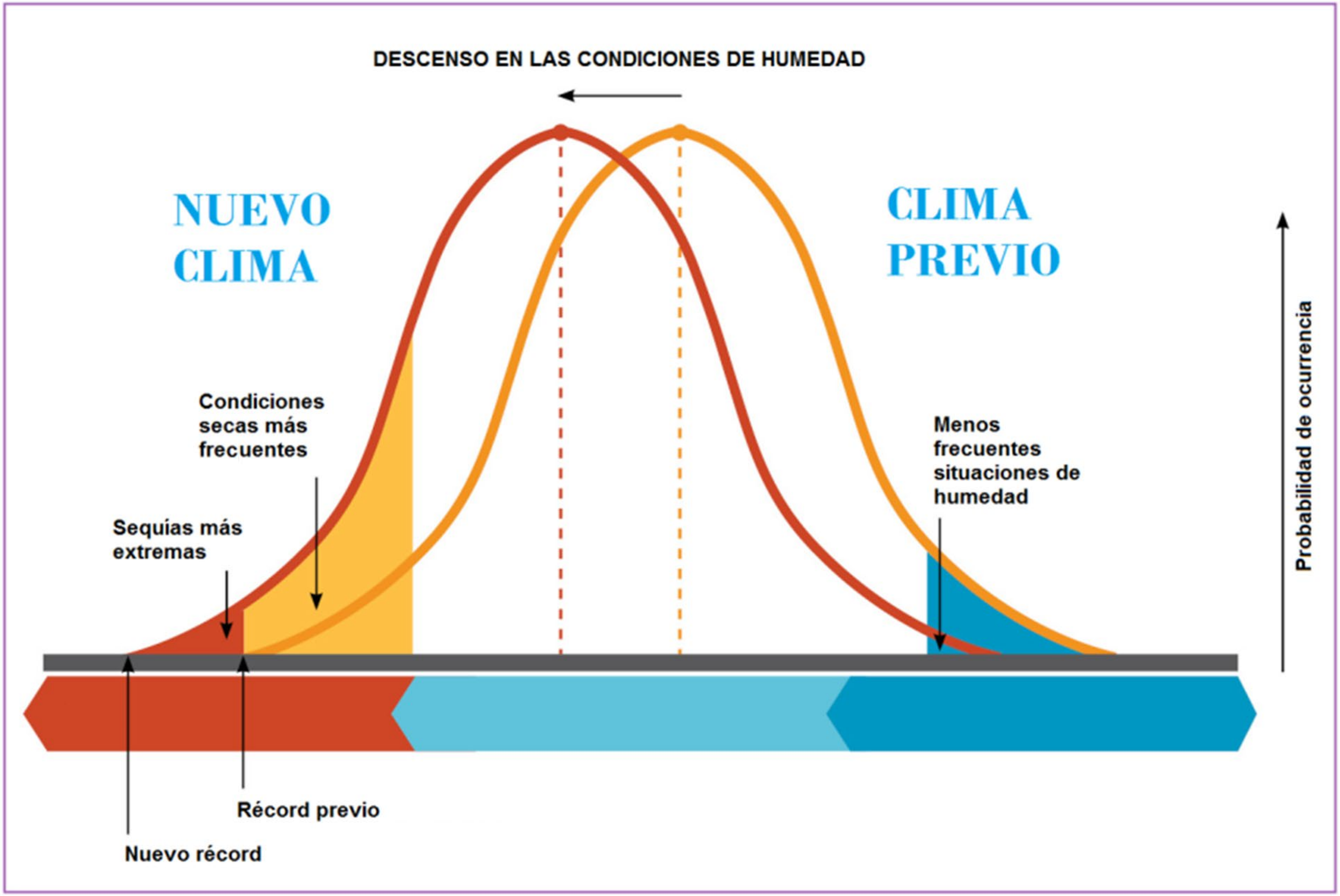
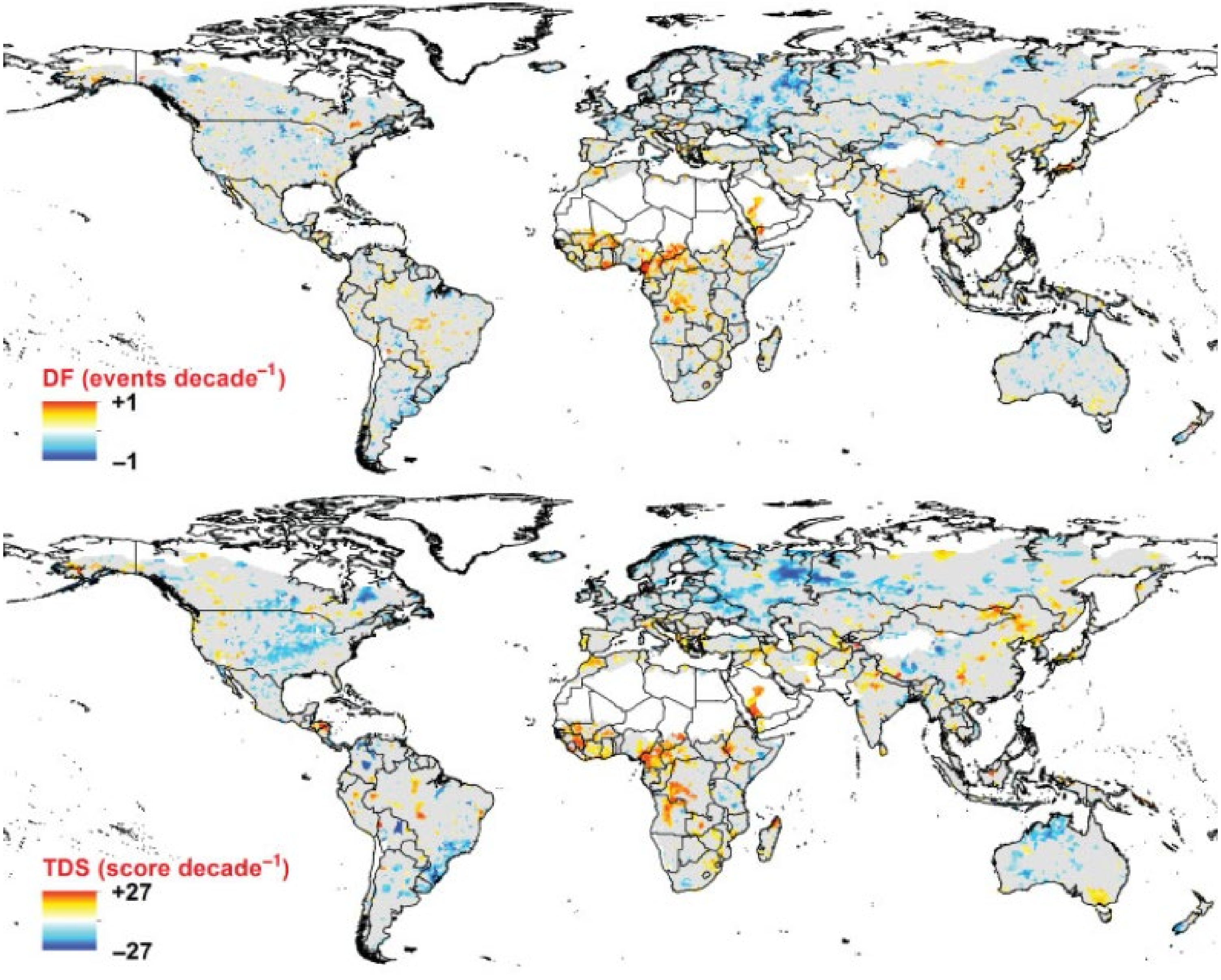
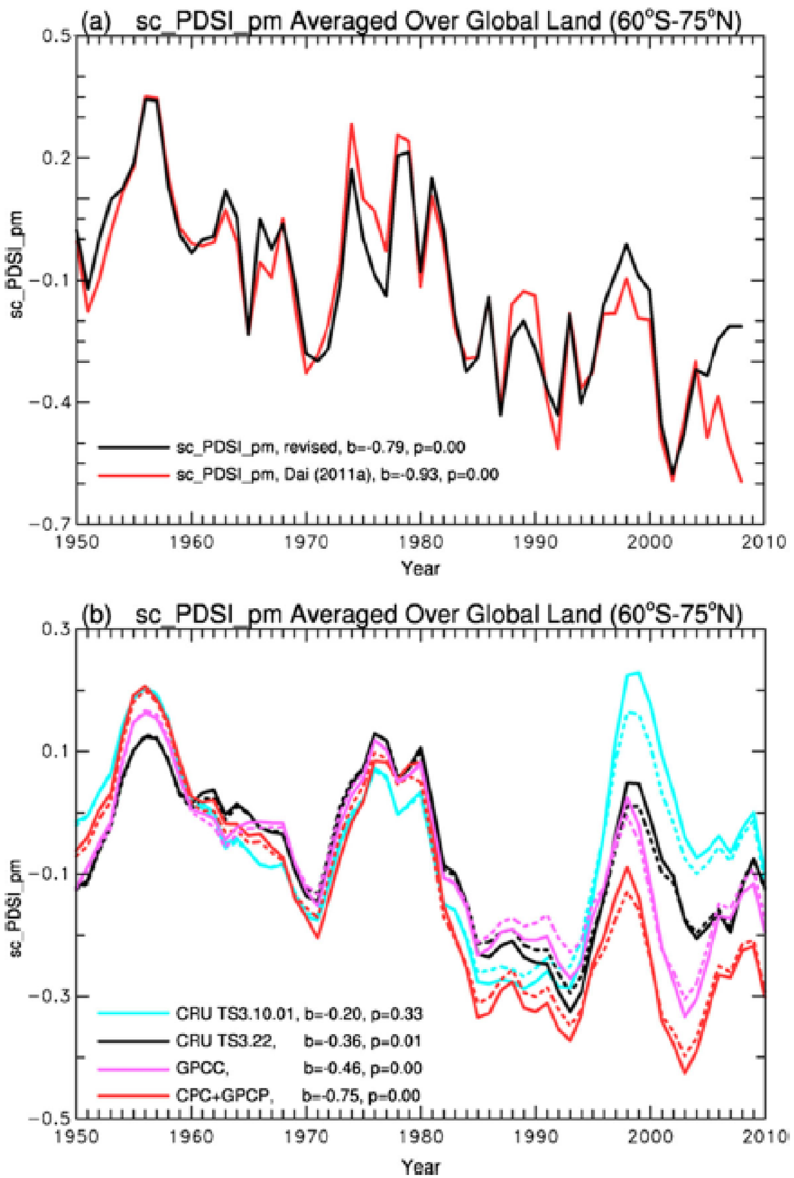
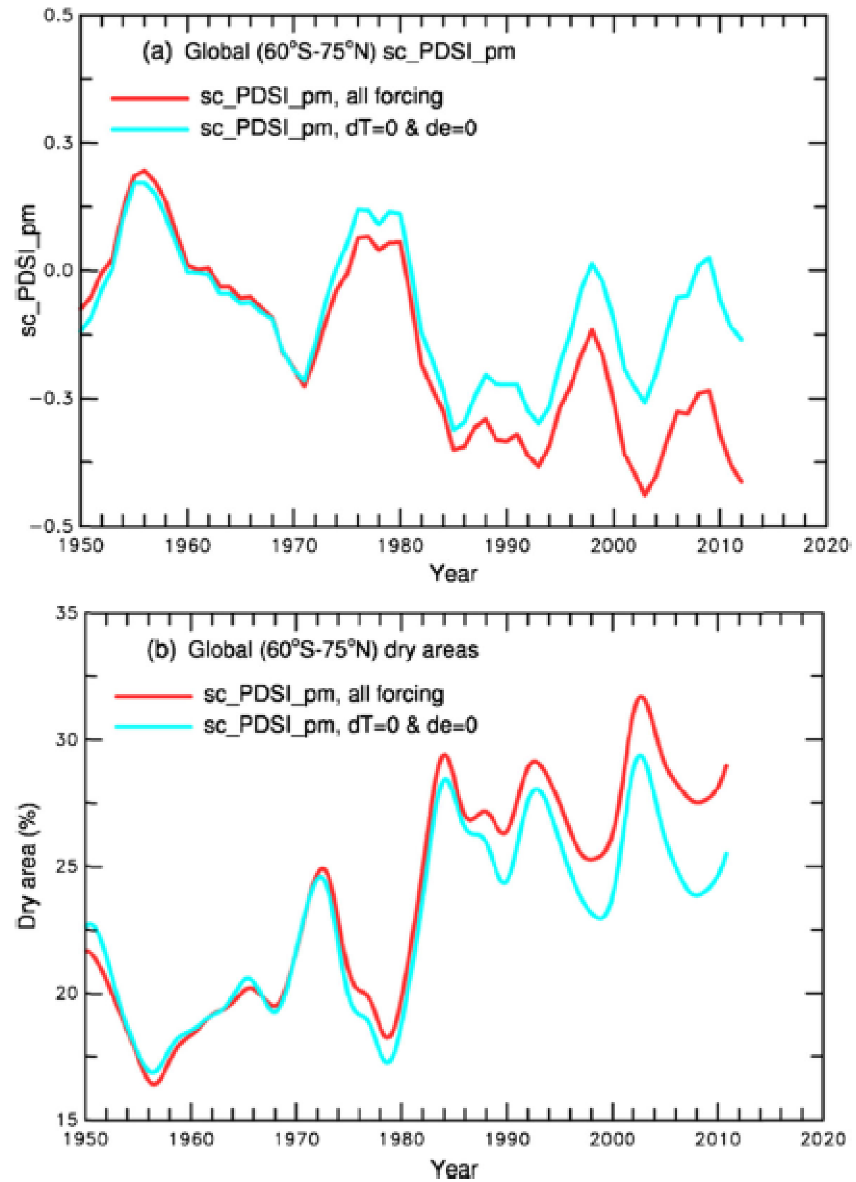
Consejo Superior de Investigaciones Científicas

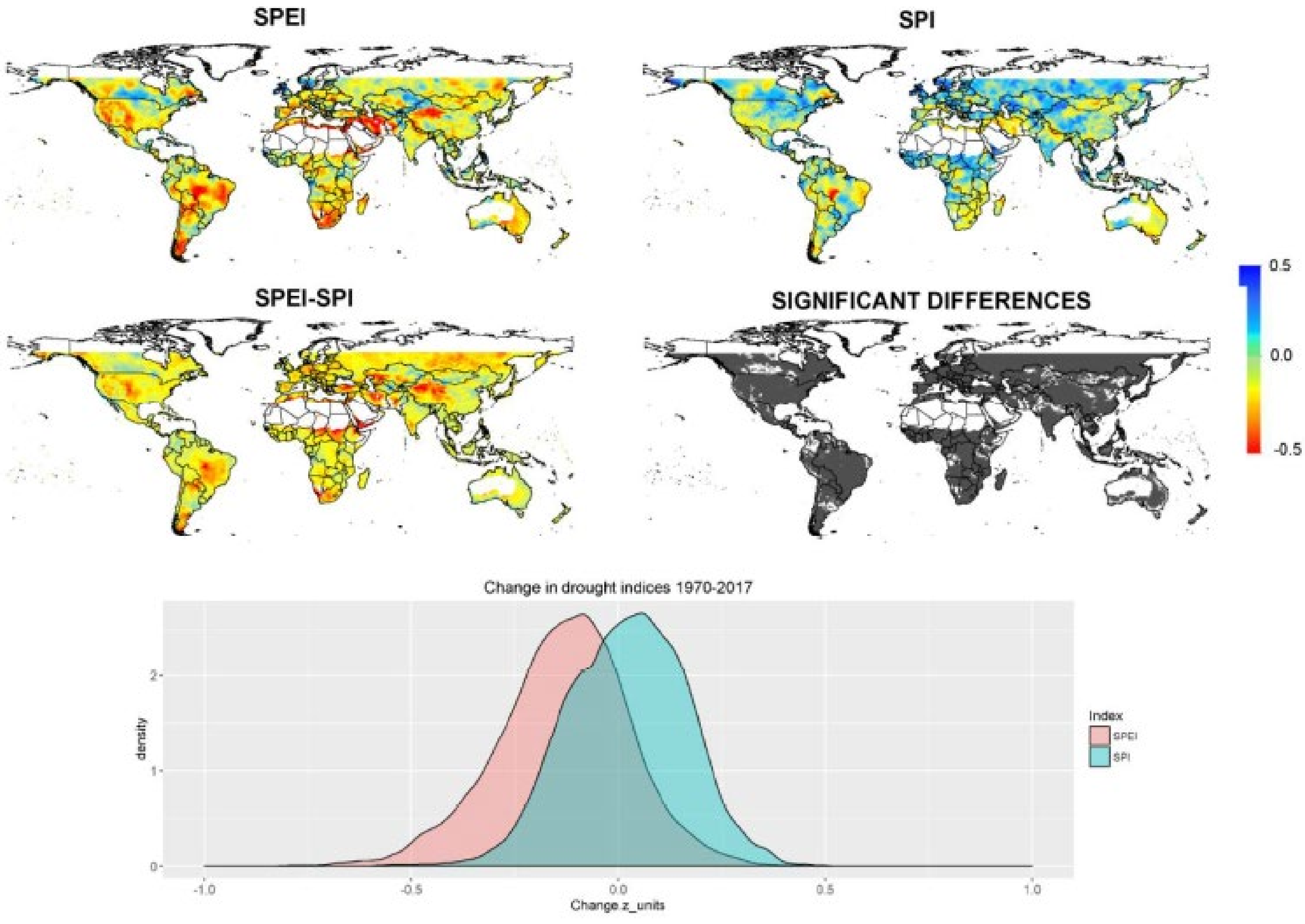
CAMBIOS EN LAS CONDICIONES DE SEQUÍA

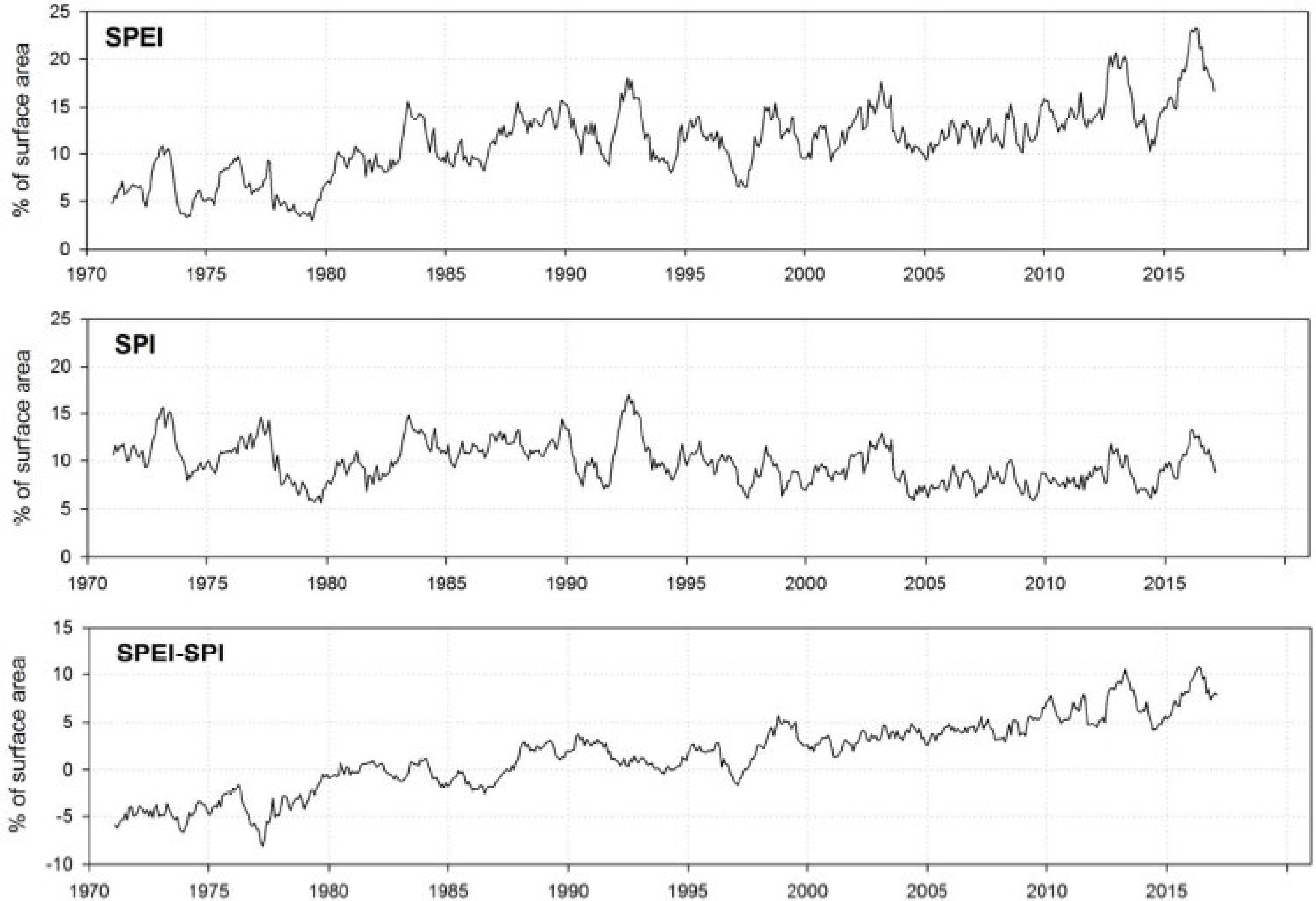


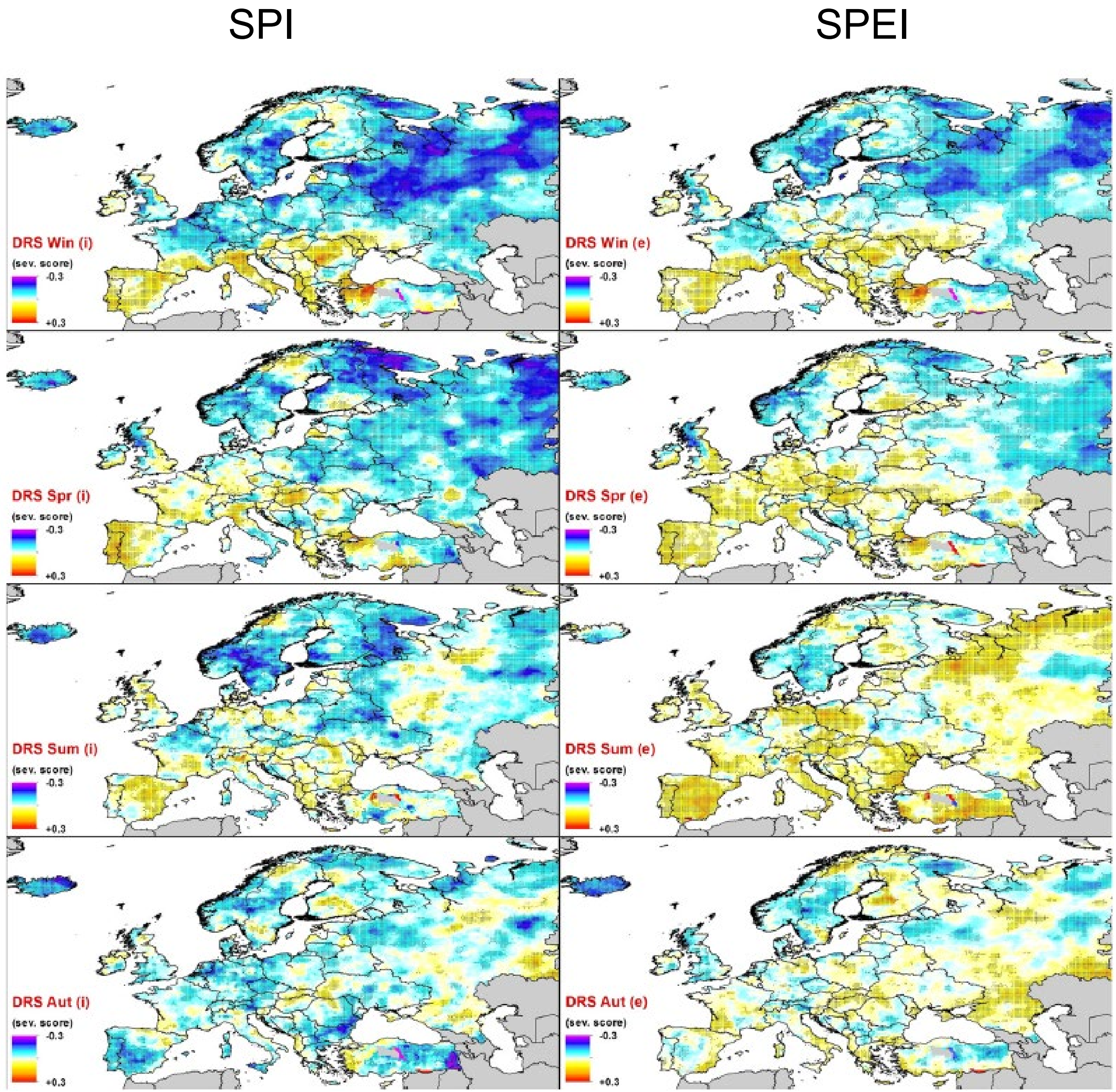

DF (events decade^{-1})
+1
–1
TDS (score decade^{-1})
+27
–27


(a) sc_PDSI_pm Averaged Over Global Land (60°S-75°N)
sc_PDSI_pm
Year
sc_PDSI_pm, revised, b=-0.79, p=0.00
sc_PDSI_pm, Dai (2011a), b=-0.93, p=0.00
(b) sc_PDSI_pm Averaged Over Global Land (60°S-75°N)
sc_PDSI_pm
Year
CRU TS3.10.01, b=-0.20, p=0.33
CRU TS3.22, b=-0.36, p=0.01
GPCC, b=-0.46, p=0.00
CPC+GPCP, b=-0.75, p=0.00

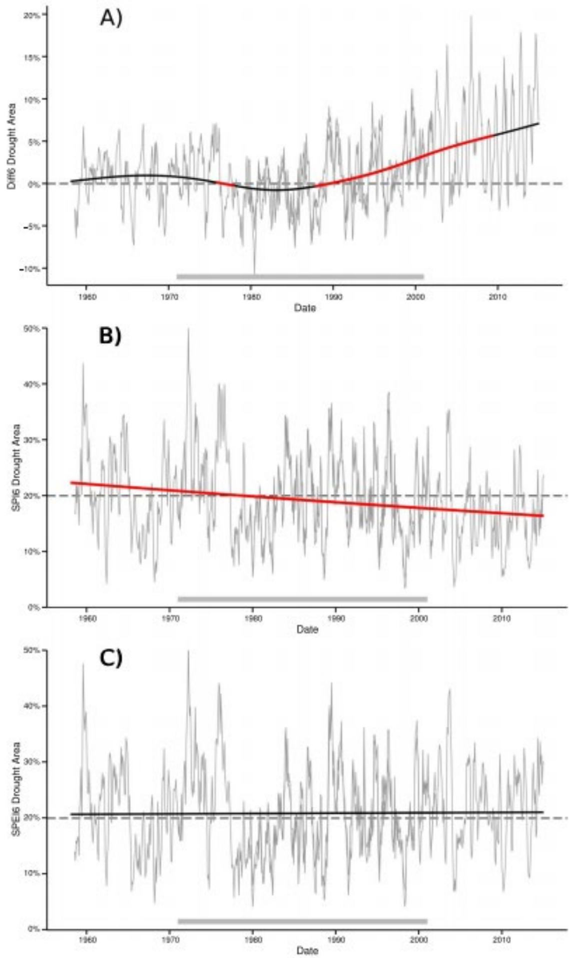

(a) Global (60°S-75°N) sc_PDSI_pm
sc_PDSI_pm, all forcing
sc_PDSI_pm, dT=0 & de=0
sc_PDSI_pm
Year
(b) Global (60°S-75°N) dry areas
sc_PDSI_pm, all forcing
sc_PDSI_pm, dT=0 & de=0
Dry area (%)
Year

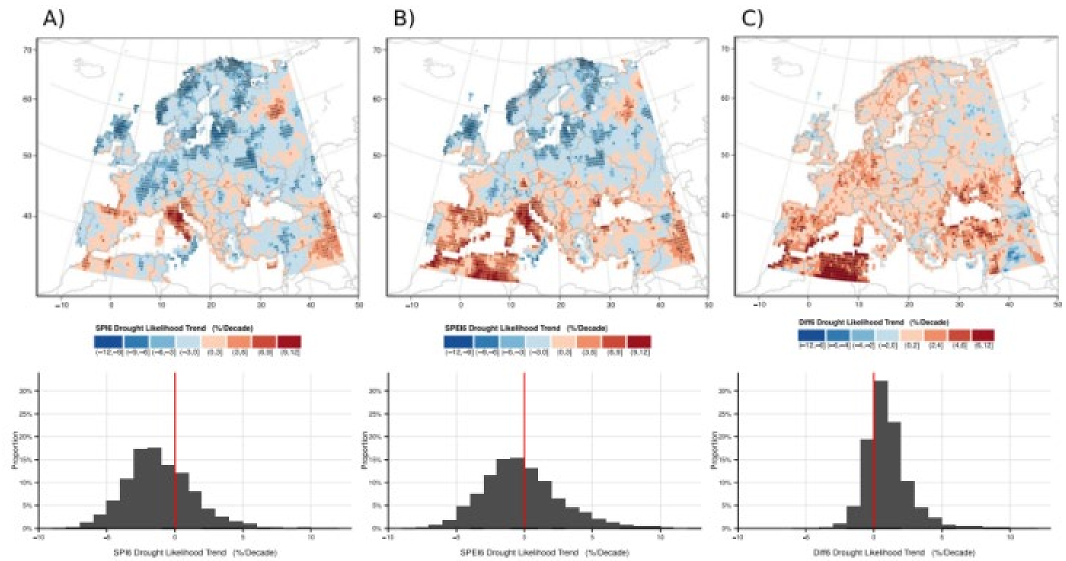

SPEI
SPI
SPEI-SPI
SIGNIFICANT DIFFERENCES
0.5
0.0
-0.5
Change in drought indices 1970-2017
density
Change.z_units
Index
SPEI
SPI
-1.0
-0.5
0.0
0.5
1.0
0
1
2


SPEI
SPI
SPEI-SPI
% of surface area
% of surface area
% of surface area
0
5
10
15
20
25
-10
-5
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015


SPI
SPEI
DRS Win (i)
(sev. score)
-0.3
+0.3
DRS Win (e)
(sev. score)
-0.3
+0.3
DRS Spr (i)
(sev. score)
-0.3
+0.3
DRS Spr (e)
(sev. score)
-0.3
+0.3
DRS Sum (i)
(sev. score)
-0.3
+0.3
DRS Sum (e)
(sev. score)
-0.3
+0.3
DRS Aut (i)
(sev. score)
-0.3
+0.3
DRS Aut (e)
(sev. score)
-0.3
+0.3

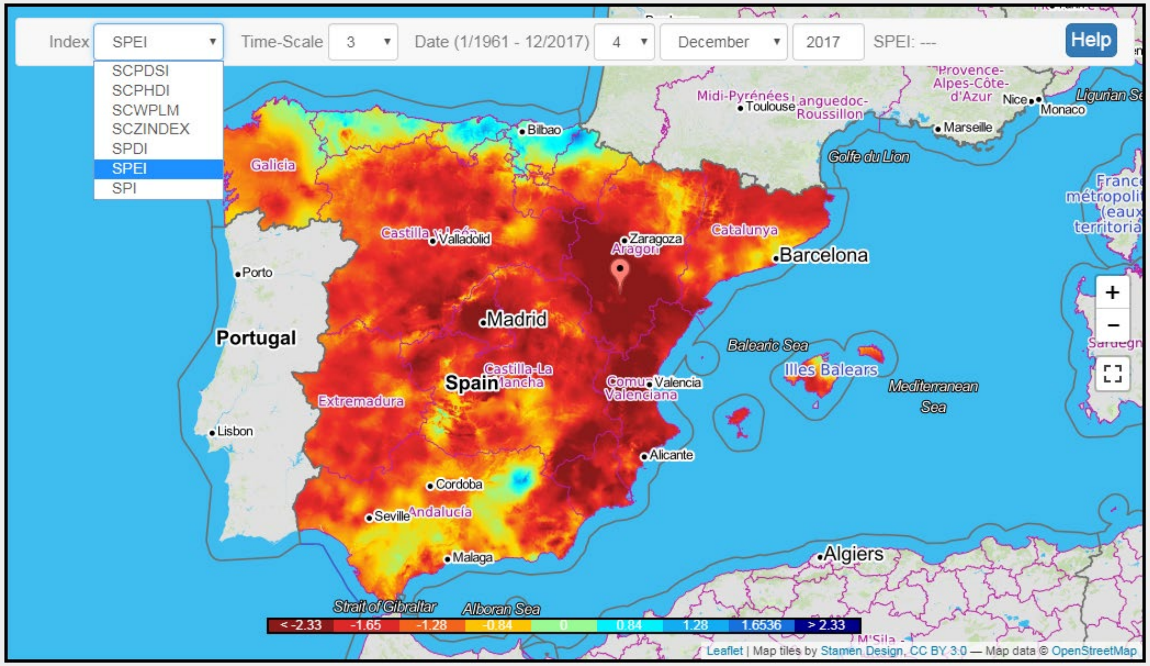
Seasonal Drought Severity	Winter				Spring				Summer				Autumn			
Tendency over period	1950-2014		1981-2014		1950-2015		1981-2015		1950-2014		1981-2014		1950-2014		1981-2014	
Macro-Region / Indicator	SPI	SPEI	SPI	SPEI	SPI	SPEI	SPI	SPEI	SPI	SPEI	SPI	SPEI	SPI	SPEI	SPI	SPEI
Iberian Peninsula	+	+	+	+	+	+	−	−	−	+	−	+	-	−	-	−
South France and Italy	+	+	−	−	−	−	−	−	−	+	−	+	-	−	-	−
The Balkans	−	−	−	−	-	-	−	−	−	+	−	+	-	−	−	−
Greece, Turkey, Cyprus	+	+	−	−	−	+	-	+	−	+	−	+	-	−	−	−
North France and Benelux	-	-	-	-	−	+	+	+	-	−	−	−	-	−	−	−
Central Europe	-	−	−	+	−	+	−	+	−	+	-	−	-	−	-	−
Eastern Europe	+	+	−	+	−	+	-	−	−	+	-	+	−	−	−	+
The Baltic Republics	-	-	+	+	-	−	+	−	−	−	−	−	−	−	+	+
European Russia	-	-	-	−	-	-	-	−	−	+	−	−	−	−	−	+
Great Britain and Ireland	−	−	−	−	−	−	−	+	−	+	-	-	−	-	−	−
Scandinavia and Iceland	-	-	−	−	-	-	−	−	-	−	-	-	-	−	−	−

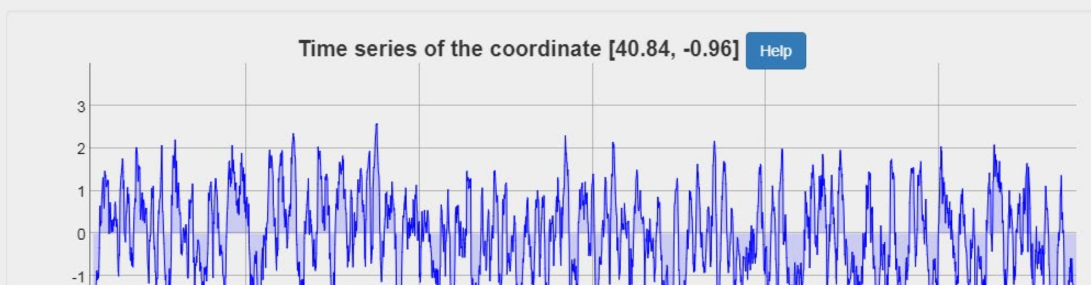


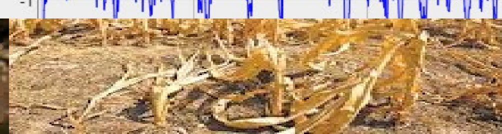


Stagge, J., et al. (2017) Sci. Reports

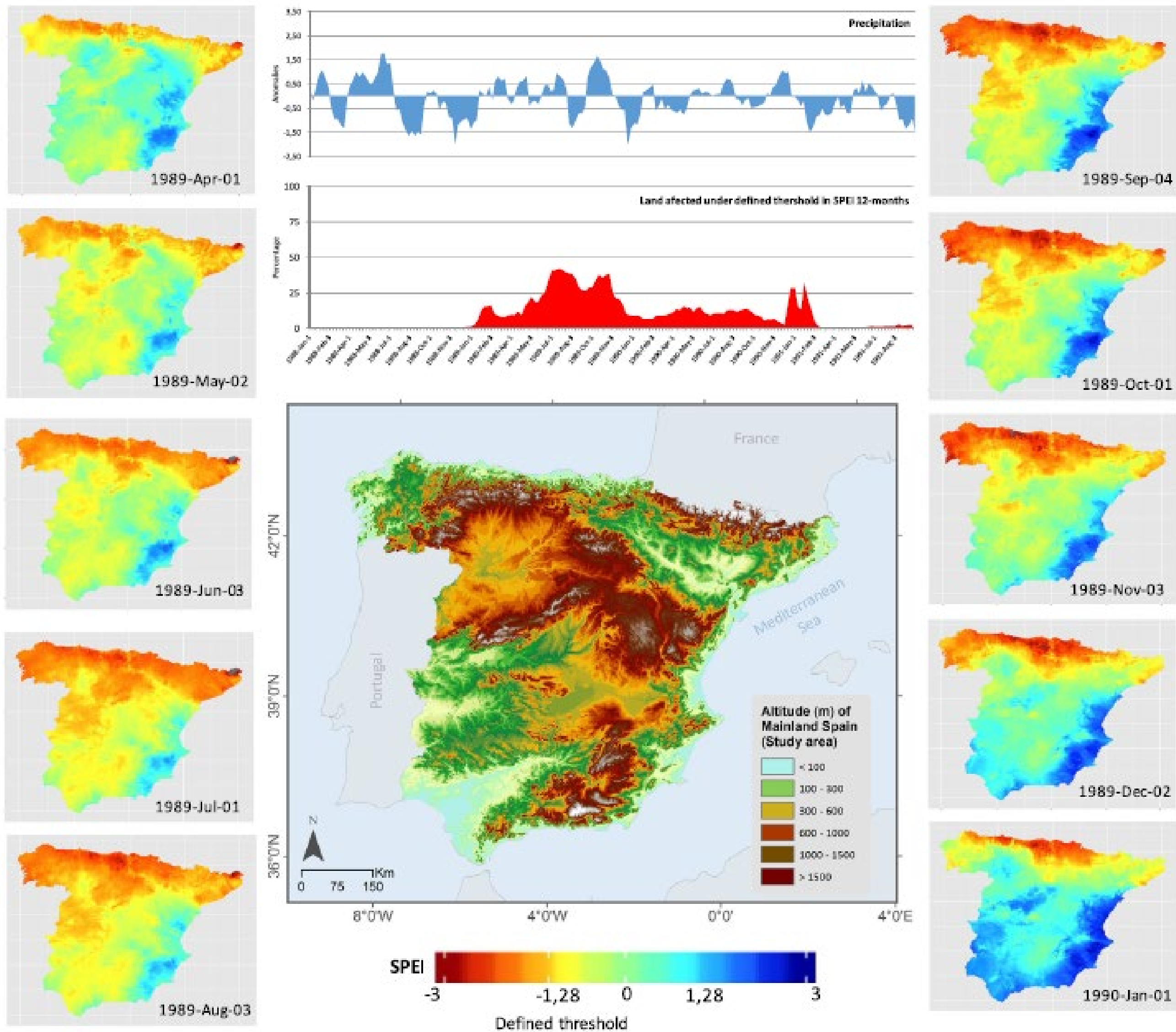
Drought indices dataset for Spain





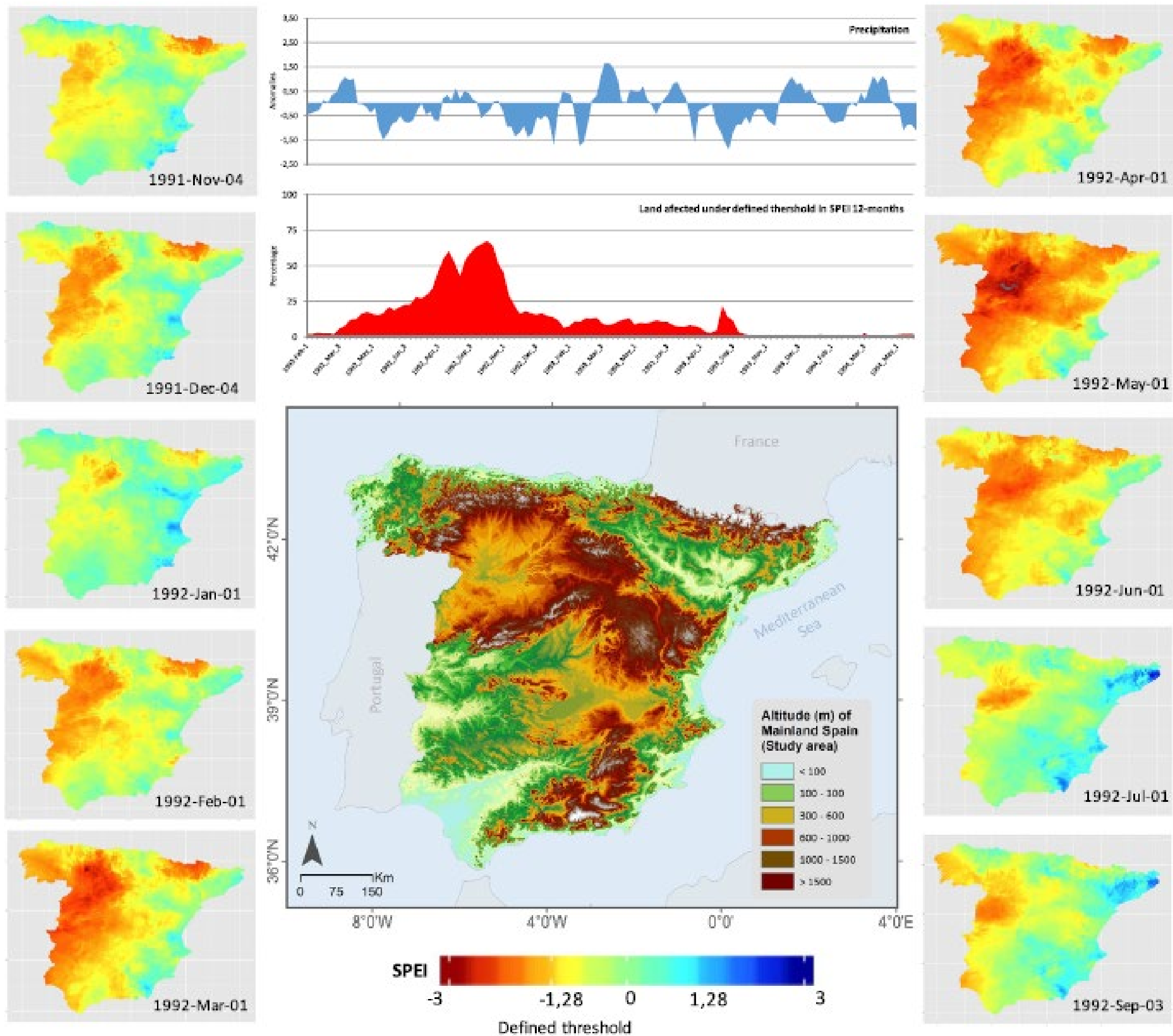


Complejidad de los patrones de sequía en España



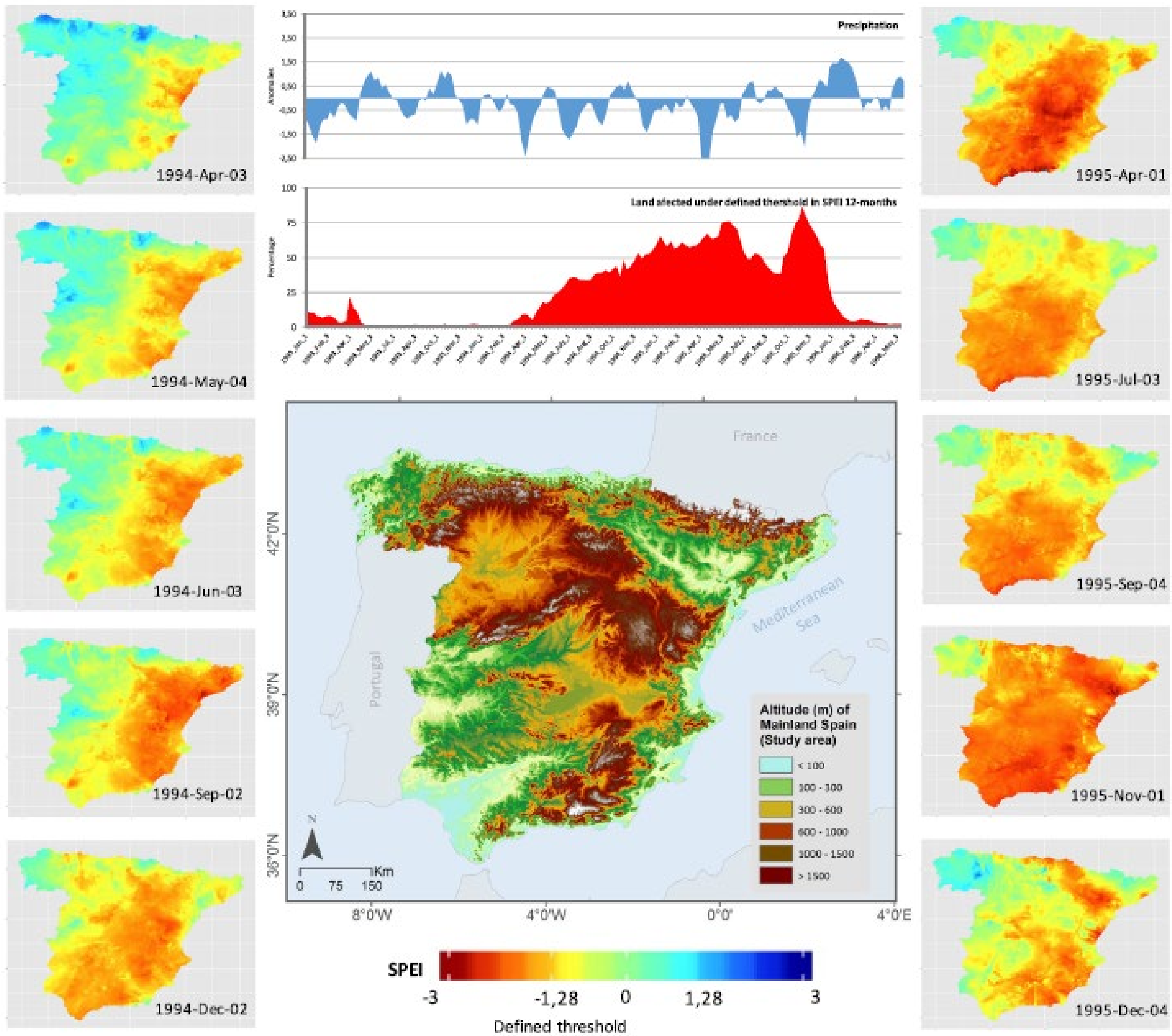
1989-1990

Complejidad de los patrones de sequía en España



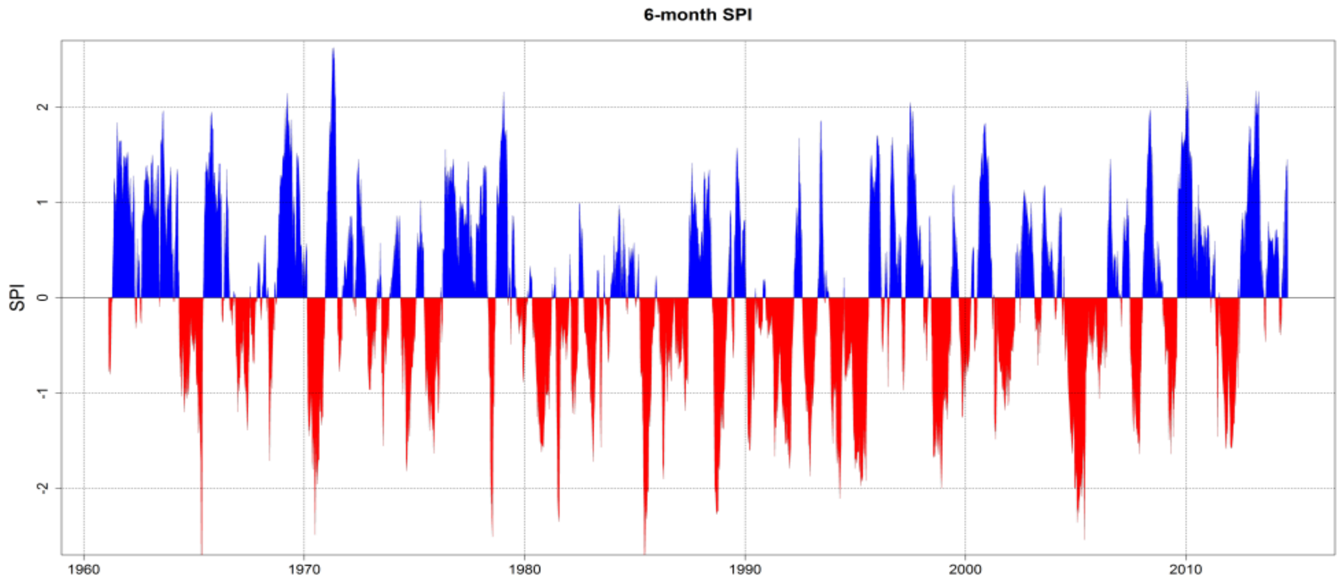
1991-1992

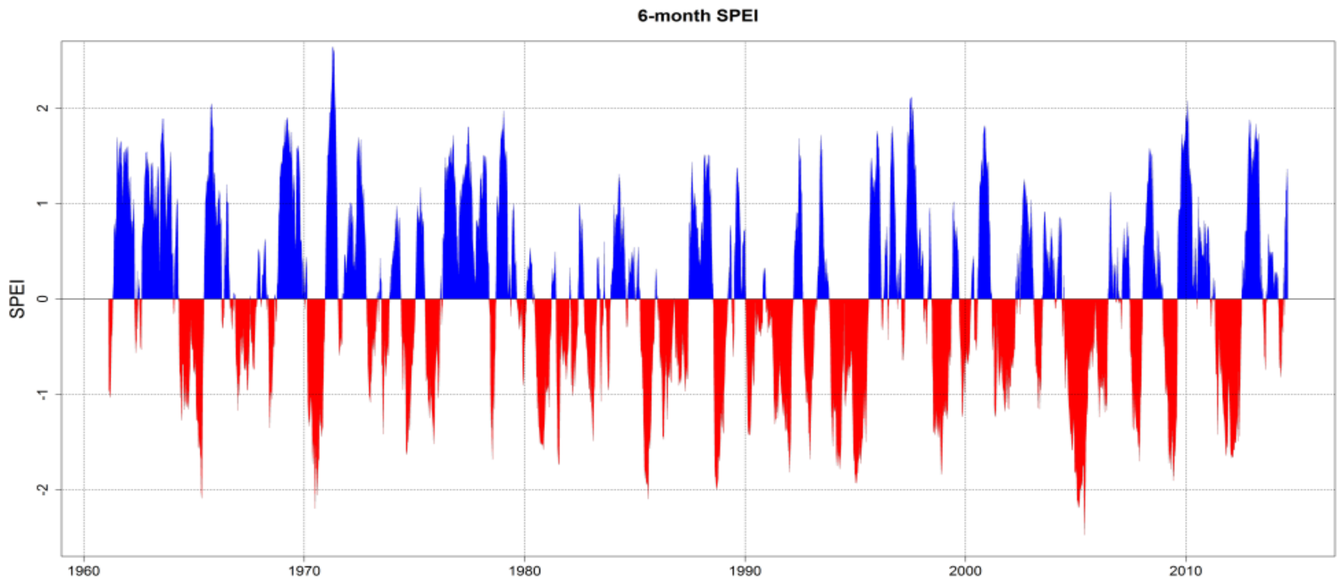
Complejidad de los patrones de sequía en España



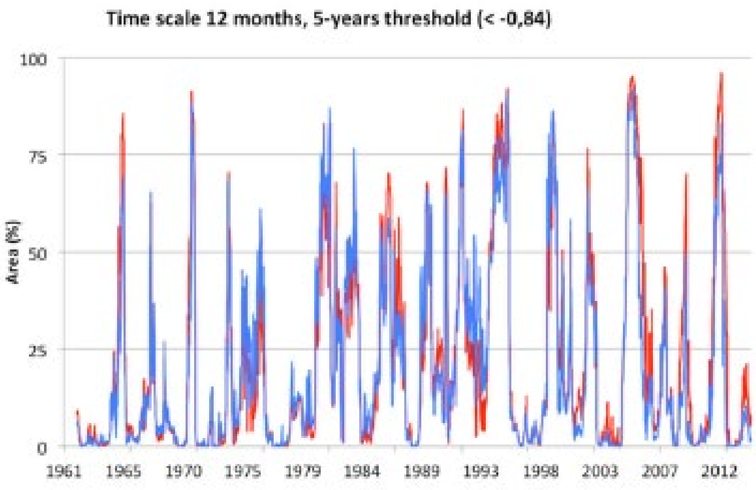
1994-1995

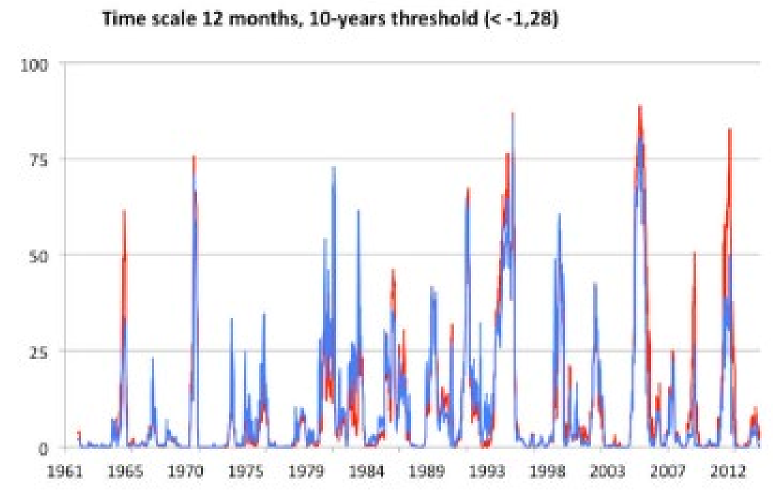
Evolución y cambio en las condiciones de sequía

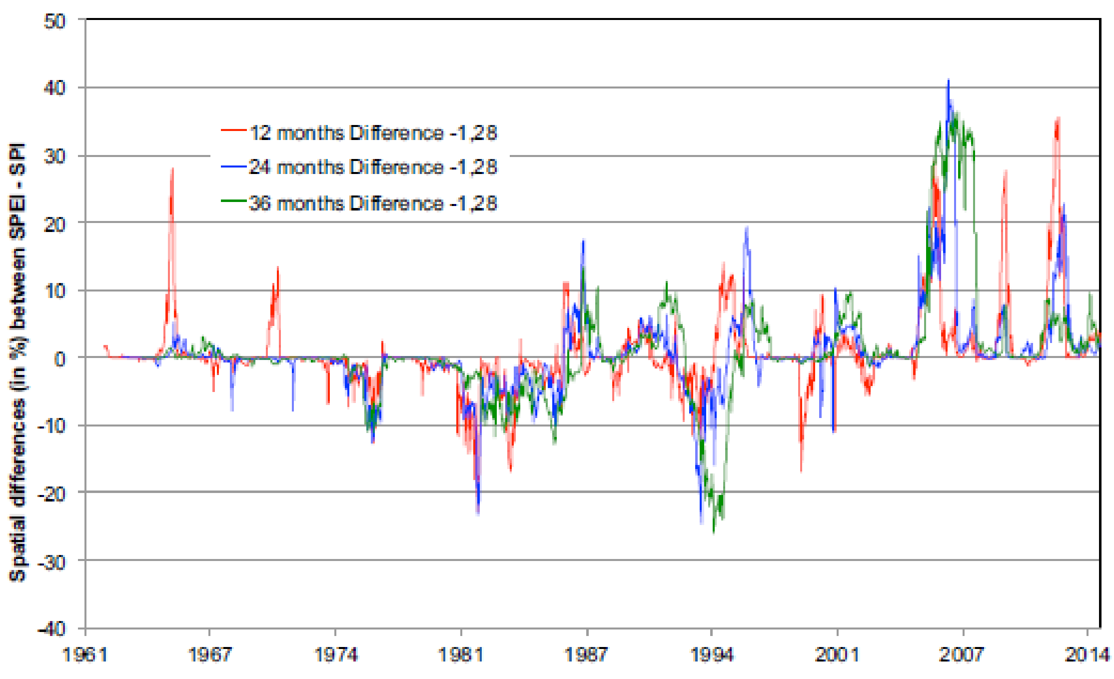




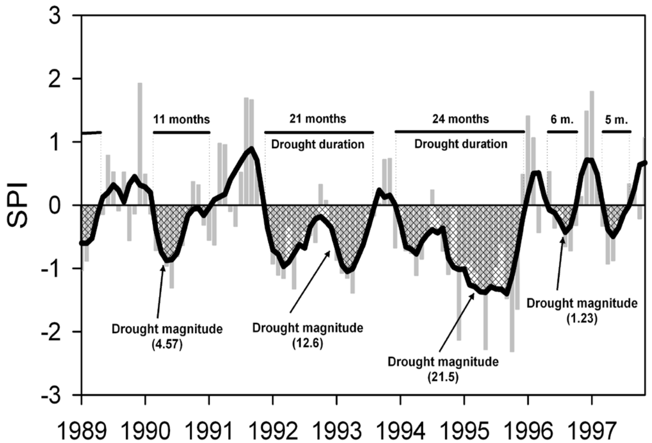
Evolución y cambio en las condiciones de sequía

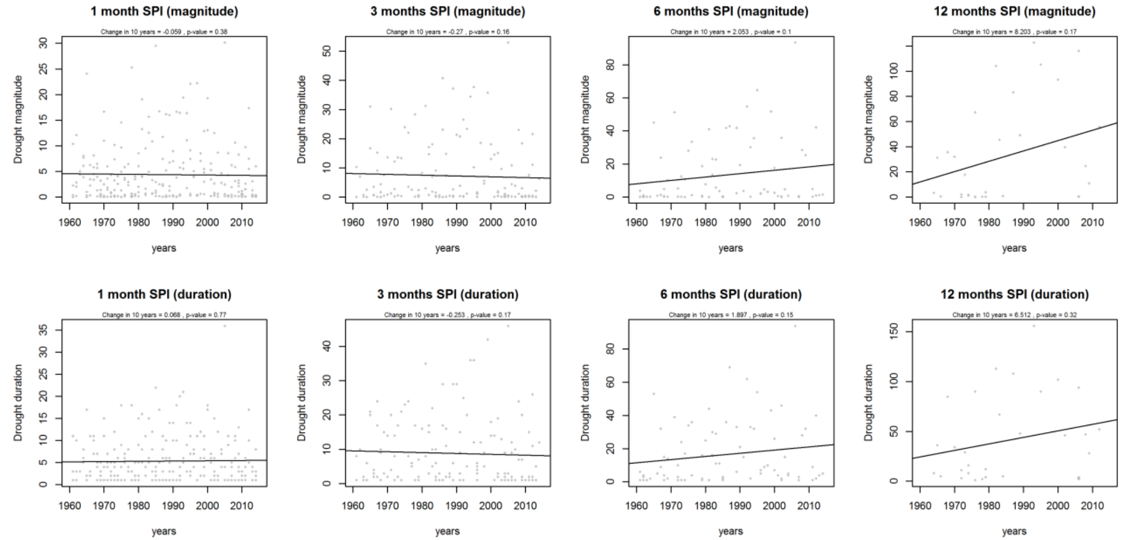


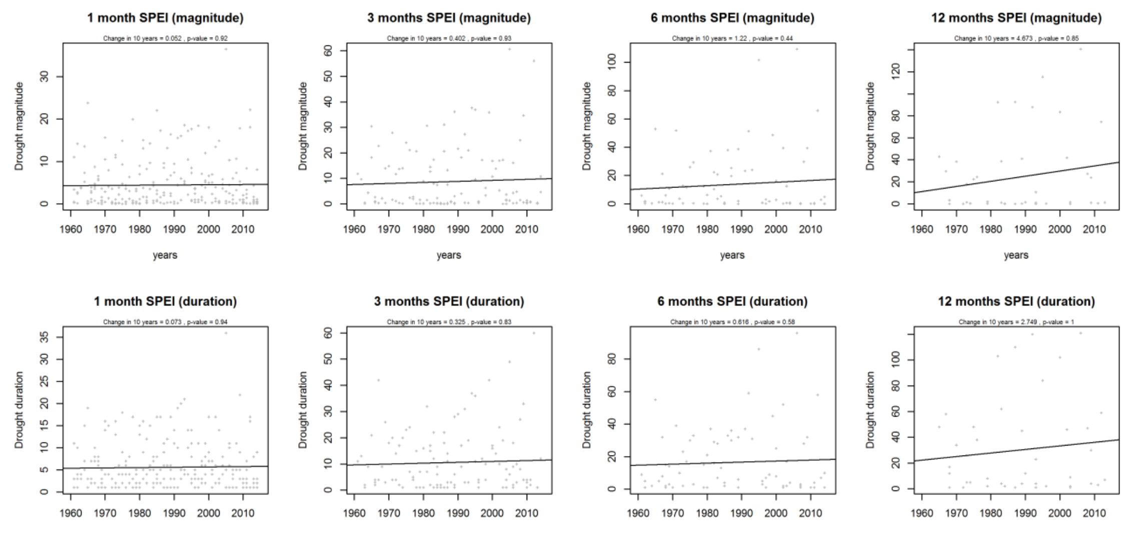




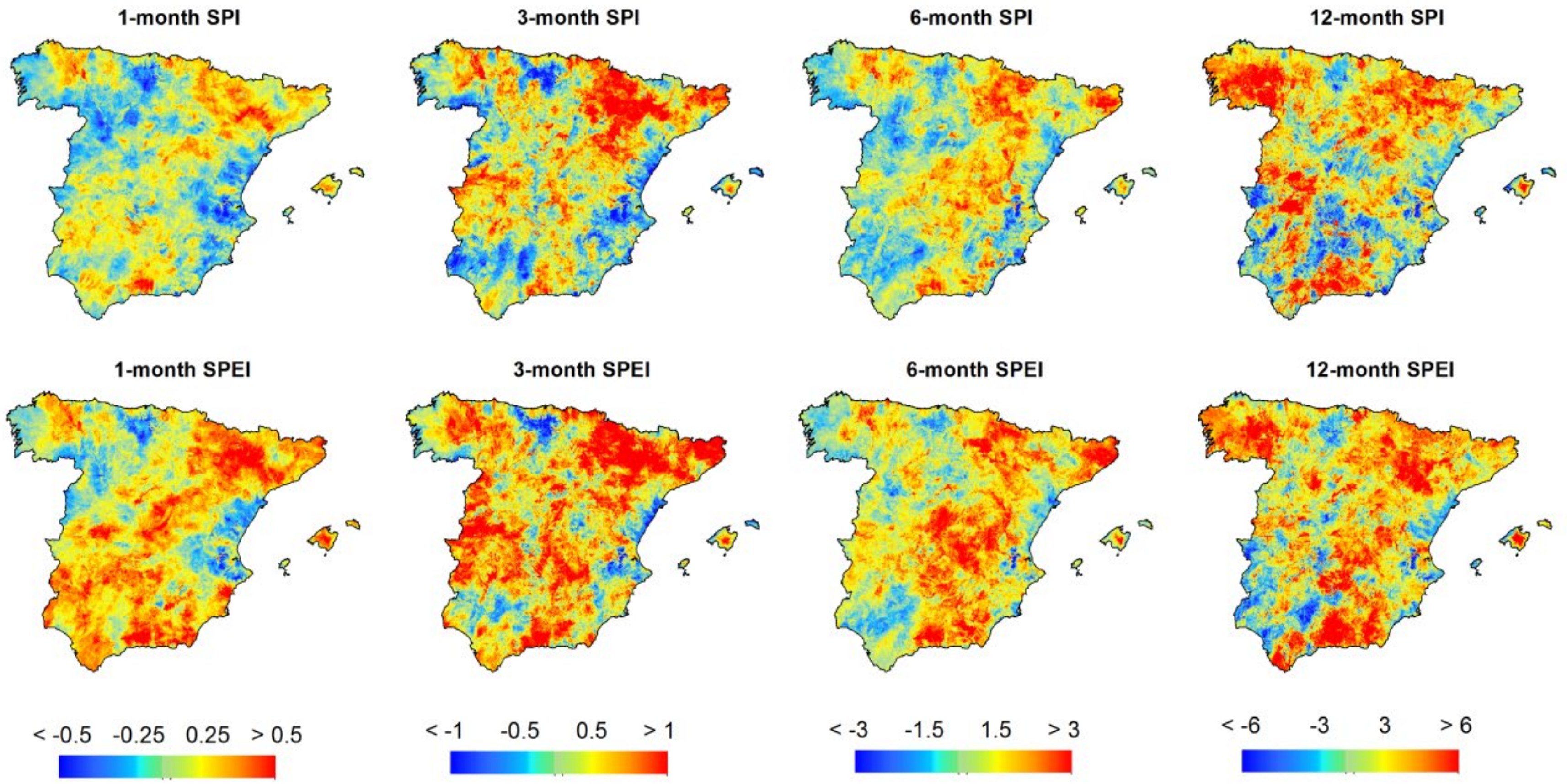
Evolución y cambio en las condiciones de sequía





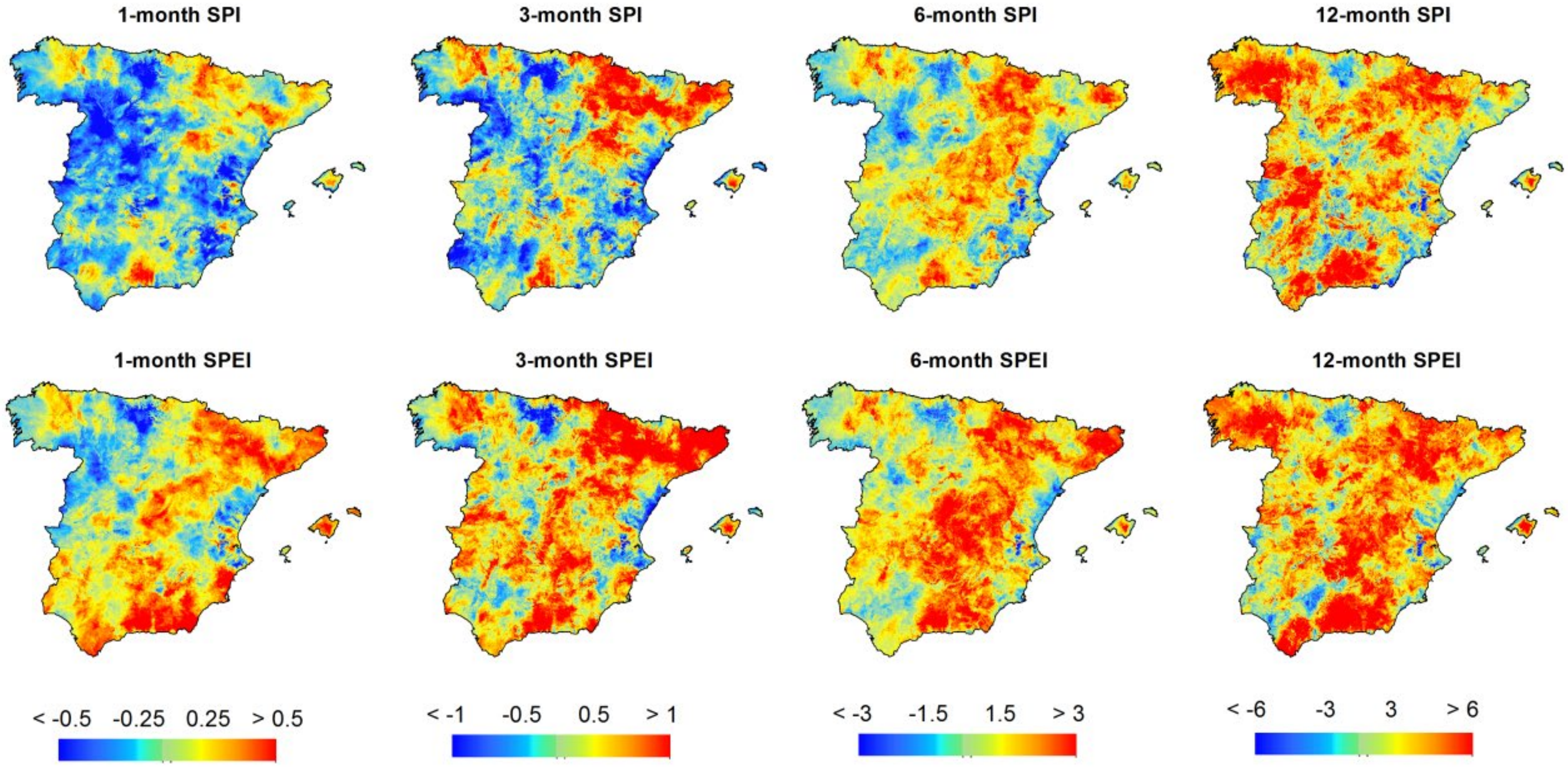


Evolución y cambio en las condiciones de sequía



Duración de los episodios de sequía

Evolución y cambio en las condiciones de sequía



Magnitud de los episodios de sequía

Evolución y cambio en las condiciones de sequía

	SPEI								SPI							
	Magnitude				Duration				Magnitude				Duration			
	1 month	**3 month**	**6 month**	**12 month**	**1 month**	**3 month**	**6 month**	**12 month**	**1 month**	**3 month**	**6 month**	**12 month**	**1 month**	**3 month**	**6 month**	**12 month**
Negative (p < 0.1)	3.63	2.91	1.45	1.56	1.10	3.07	1.74	2.09	14.61	6.01	4.76	2.25	3.94	5.06	4.38	2.47
Negative (p > 0.1)	24.27	16.41	15.46	10.40	18.23	14.49	20.35	19.62	49.93	43.26	28.25	16.42	36.73	28.38	32.26	25.70
Positive (p > 0.1)	64.24	76.30	79.39	81.04	67.44	78.10	74.29	72.10	33.09	47.85	64.26	75.23	53.96	62.85	60.38	66.05
Positive (p < 0.1)	7.86	4.37	3.70	7.00	13.23	4.33	3.63	6.19	2.37	2.88	2.73	6.10	5.37	3.71	2.98	5.78

2017

NACIONAL

Agroseguro prevé indemnizar con 208 M€ a cereales y leguminosas asegurados por sequía y heladas

SEPTIEMBRE 7, 2017

0 LIKES

El "pool" de compañías privadas del seguro agrario, Agroseguro, prevé unas indemnizaciones por siniestralidad en sequía y heladas por importe total de 208 millones de e
1.651.660 hectáreas de est
más alta de la historia del
primas abonadas por sus

MEDIO AMBIENTE

España se enfrenta a una de las sequías más destructivas de la historia

España se enfrenta en 2017 a una de las
sequía igual el futuro? | Martes,

Barcelona y Girona, en prealerta por sequía

• El nivel de la reserva de agua en los embalses del Ter está en un 56%, tras un año hidrológico que se considera seco

La Generalitat ha decretado la prealerta por sequía en la región de Barcelona y Girona (La Vanguardia)

EN LA MANCOMUNIDAD DEL TORCÓN

La sequía deja las primeras restricciones de agua para consumo humano en Castilla-La Mancha

EL PAÍS — ESPAÑA

ANDALUCÍA CATALUÑA C. VALENCIANA GALICIA MADRID PAÍS VASCO MÁS COMUNIDADES TITULARES »

HIDROLOGÍA ›

Retrato de una España atrapada en la sequía

El año hidrológico ha concluido con cifras preocupantes. Estos son los datos que fundamentan la alarma

MEDIO AMBIENTE

Radiografía de la sequía extrema en España

• Las reservas de agua de los embalses están ahora en el nivel más bajo de los últimos 22 años
• La peor situación está en la zona sureste peninsular (cuencas de los ríos Segura y Júcar) y en la cuenca del Duero

No es la "peor sequía en 20 años", será la peor de la historia de España: el desastre en datos

aramos el actual periodo con las grandes sequías recientes (1980-1984 y 1992-1995) y los
stros no dejan lugar a dudas. Aún no ha terminado pero quedará en los libros de Historia

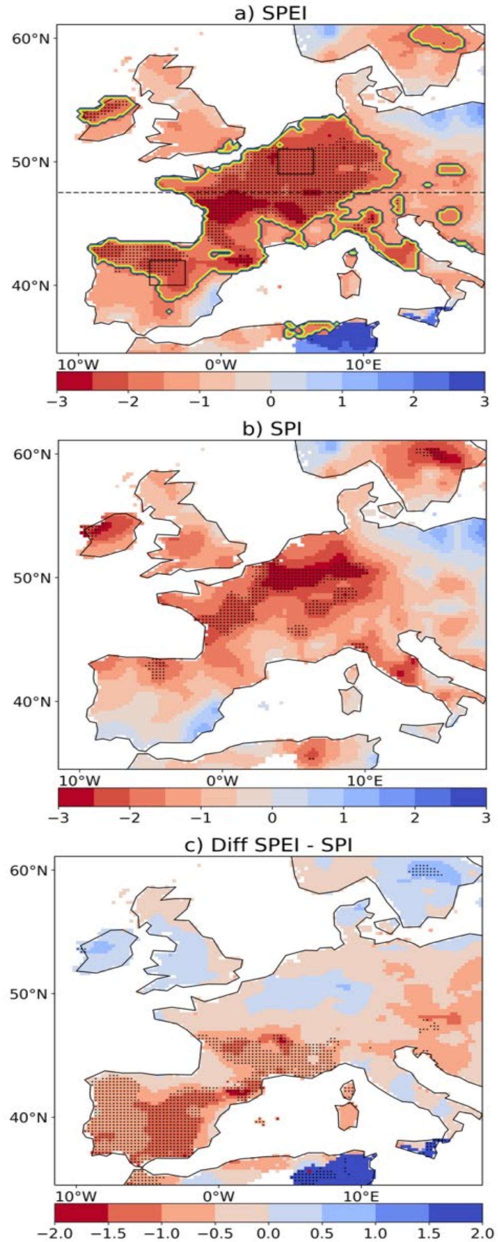
EL PAÍS — ECONOMÍA

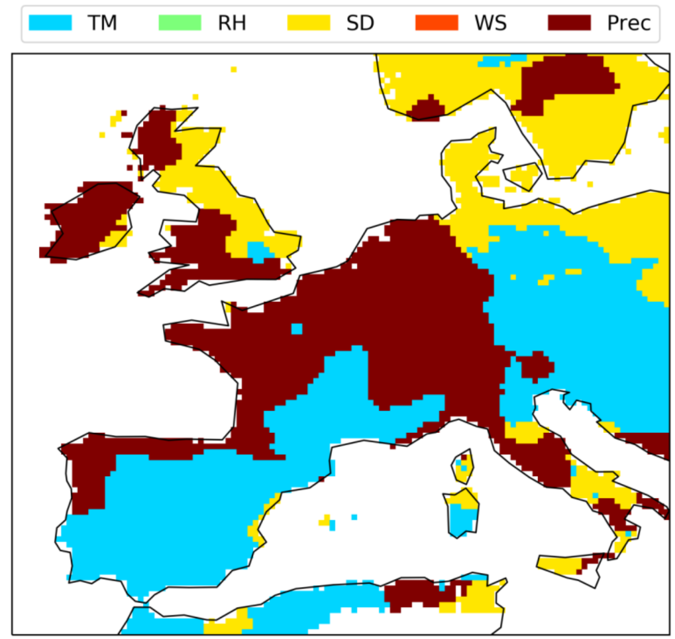
MERCADOS MIS AHORROS VIVIENDA MIS DERECHOS FORMACIÓN TITULARES » Retina CincoDías NEGOCIOS

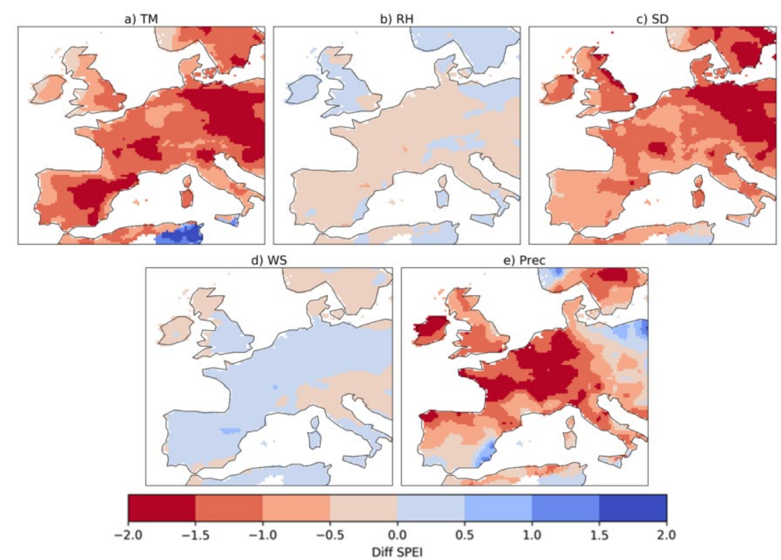
La sequía rebaja los ingresos del campo en 2.500 millones

Los pagos por indemnizaciones previstos por las compañías de seguros para agricultores se estiman en 725 millones

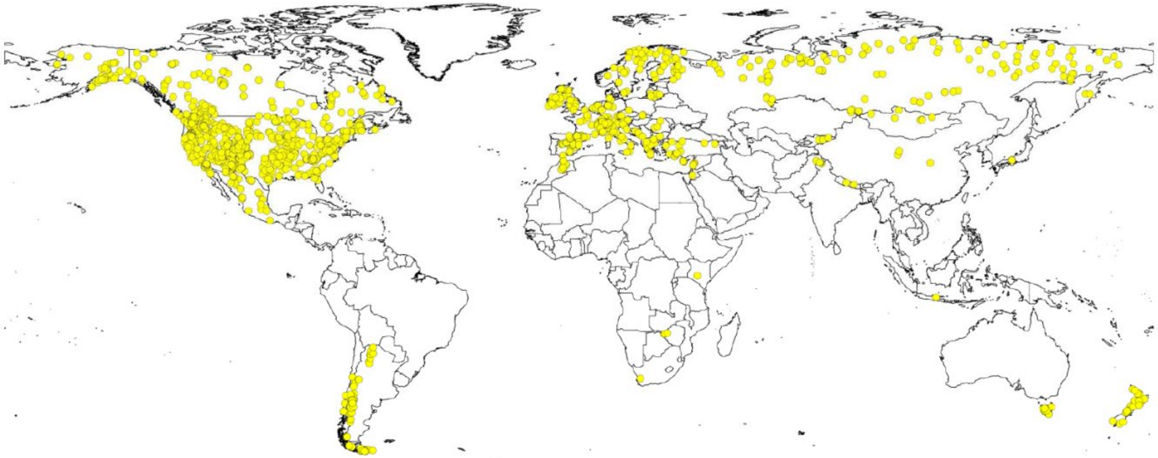
Sequía 2016/2017

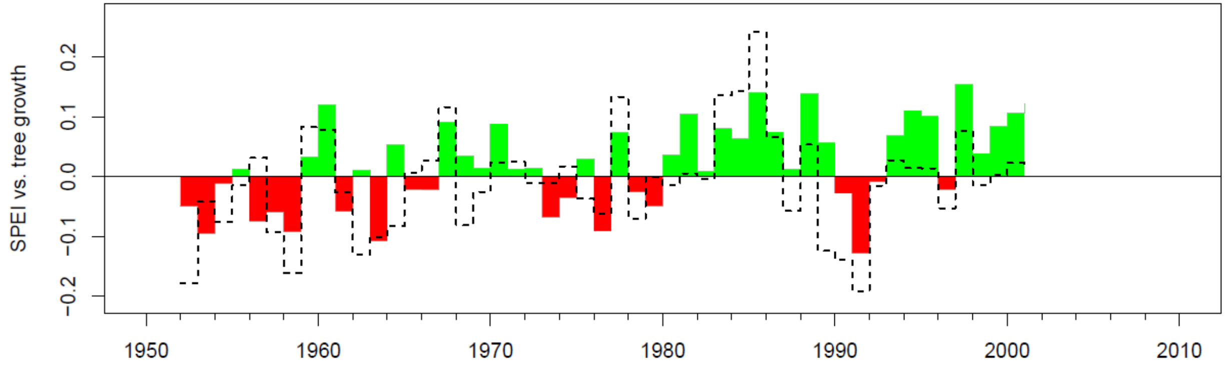






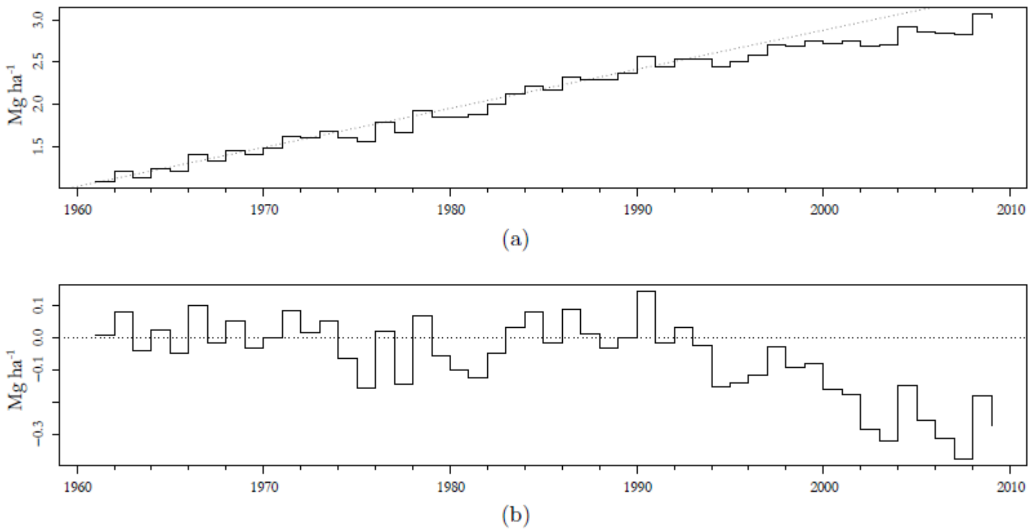
RECORDING IMPACTS: tree-ring growth

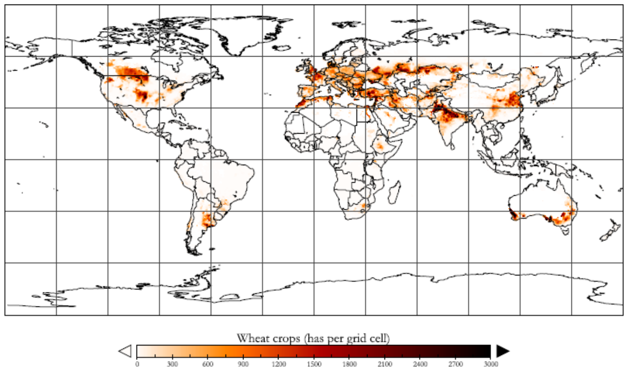


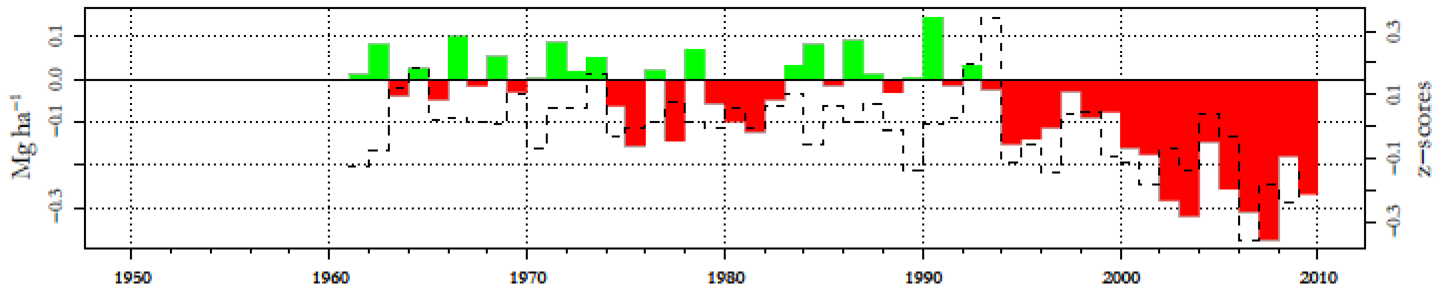


For forest tree growth, regression against SPI was significant (p-value=0.004) and explained 15.8% of the variance, while SPEI was signi cant (p-value<0.001) and explained 40.1% of the variance.

RECORDING IMPACTS: wheat yield

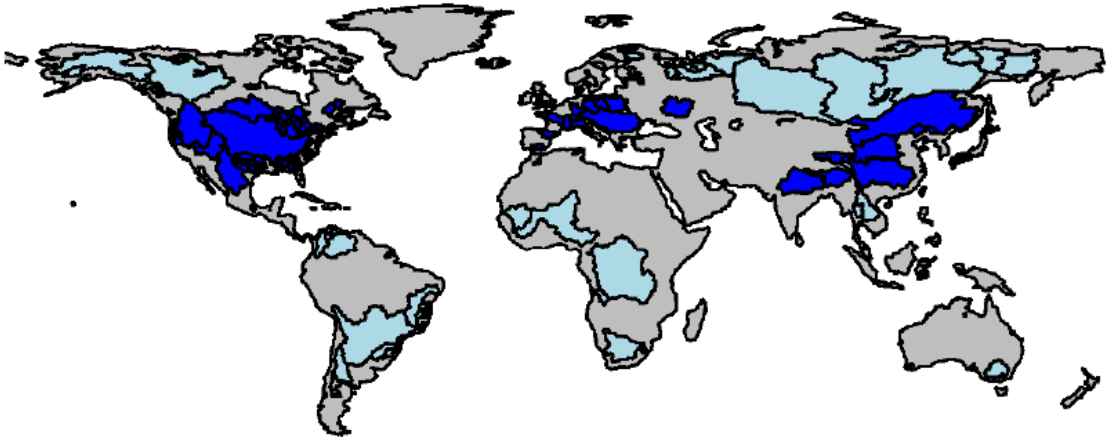


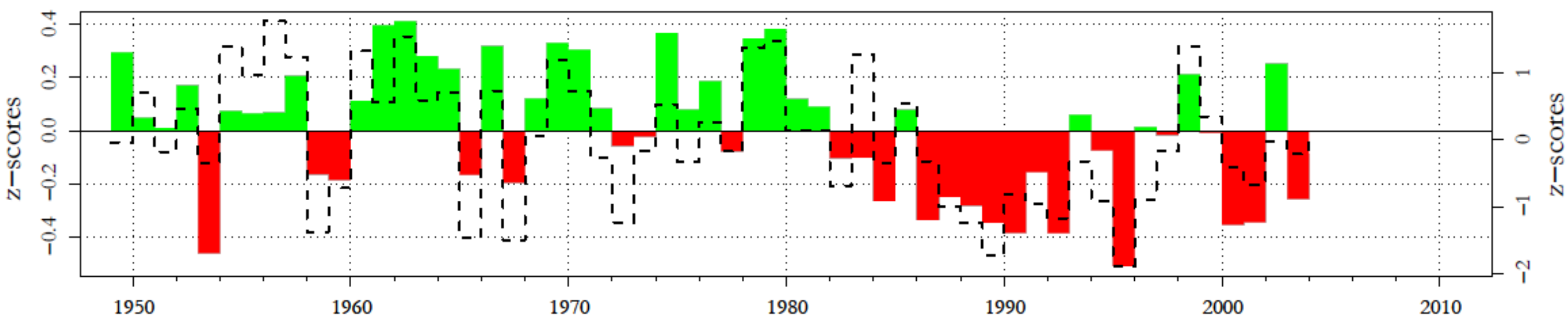




Non-significant relationship with the SPI. With the SPEI the relationship is significant (p-value<0.001, **R^2=0.545**)

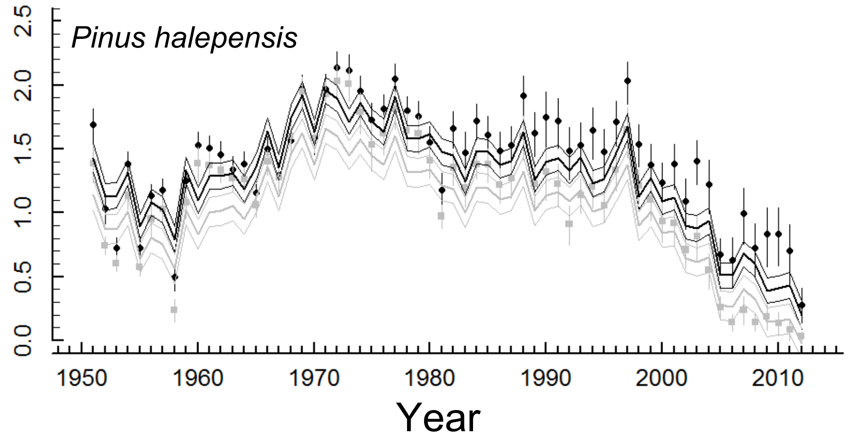
RECORDING IMPACTS: streamflows



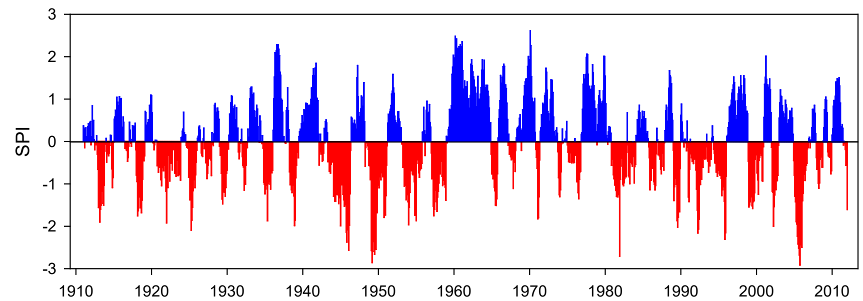


Significant relationship with the SPI (p-value<0.001, $\mathbf{R^2=0.274}$), but stronger considering the **SPEI** (p-value<0.001, $\mathbf{R^2=0.523}$).

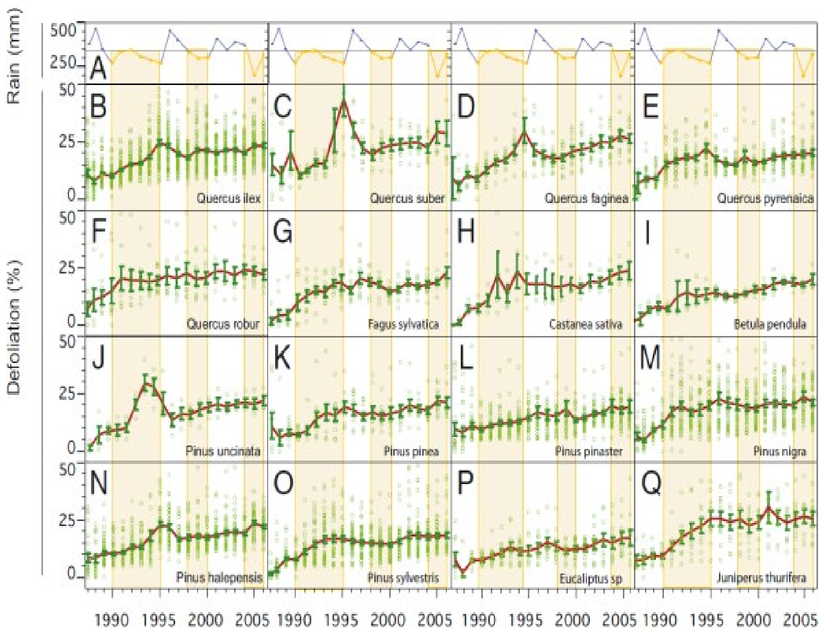
Evolución de indicadores objetivos



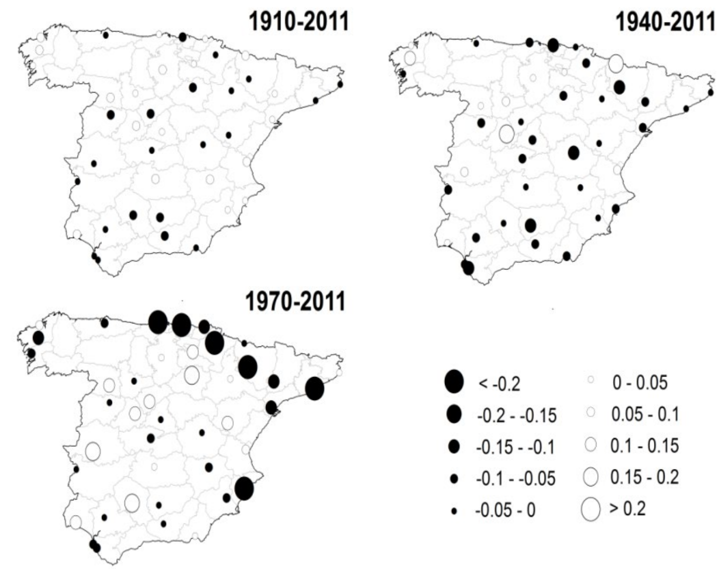
Camarero et al., (2015): Journal of Ecology



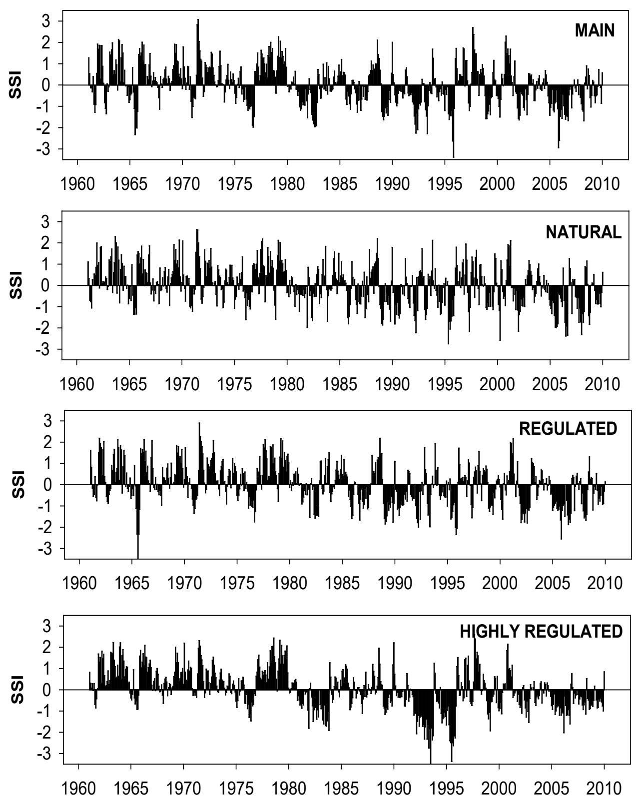
Vicente-Serrano, S.M., (2013): In Adverse Weather in Spain (Carlos García-Legaz Martínez y Francisco Valero Rodríguez Eds.).

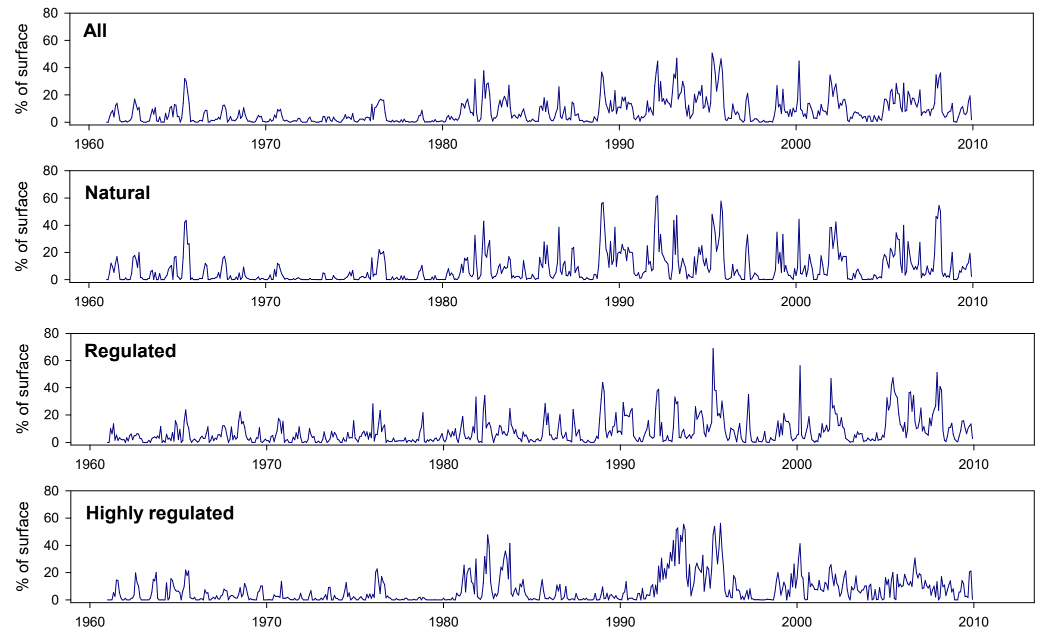


Carnicer et al., (2011): PNAS (2011), 108: 1474



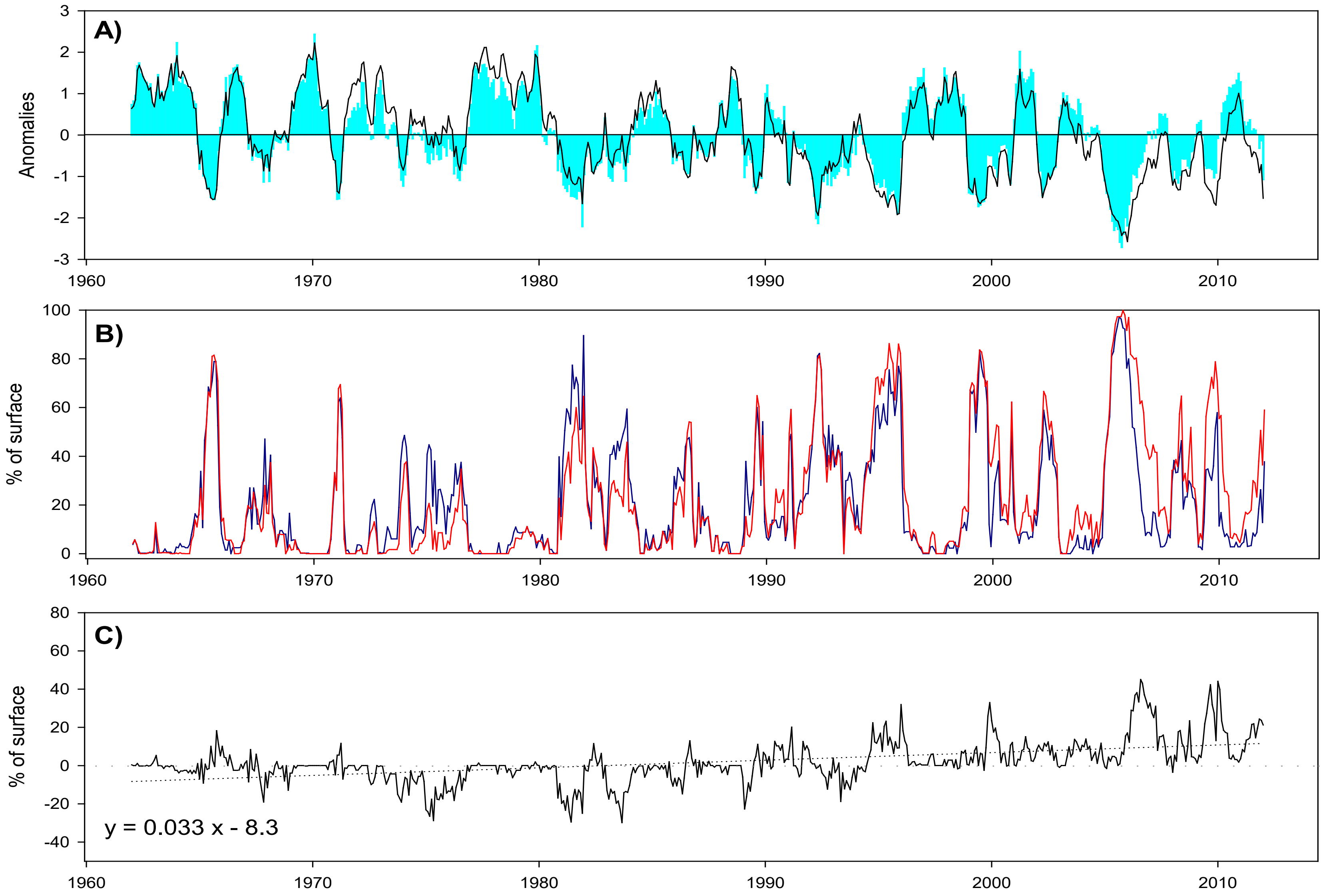
Influencia en la demanda de agua por parte de la atmósfera en la severidad de las sequías





Vicente-Serrano, S.M, et al (2014). Evidence of increasing drought severity caused by temperature rise in southern Europe. Environmental Research Letters. 9, 044001. doi:10.1088/1748-9326/9/4/044001

Influencia en la demanda de agua por parte de la atmósfera en la severidad de las sequías



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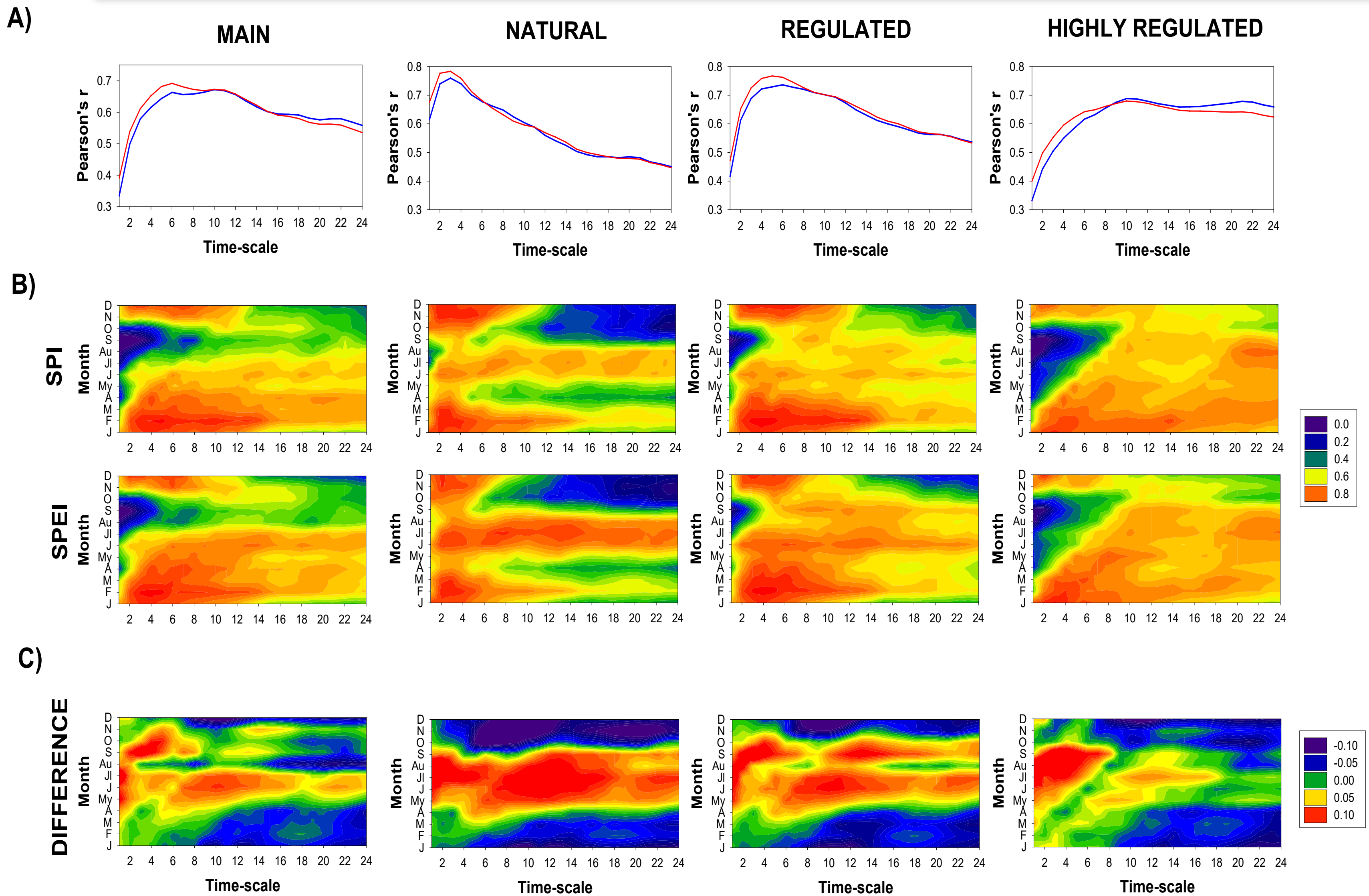
Influencia en la demanda de agua por parte de la atmósfera en la severidad de las sequías



Vicente-Serrano, S.M, et al (2014). Evidence of increasing drought severity caused by temperature rise in southern Europe. Environmental Research Letters. 9, 044001. doi:10.1088/1748-9326/9/4/044001

Escenarios futuros

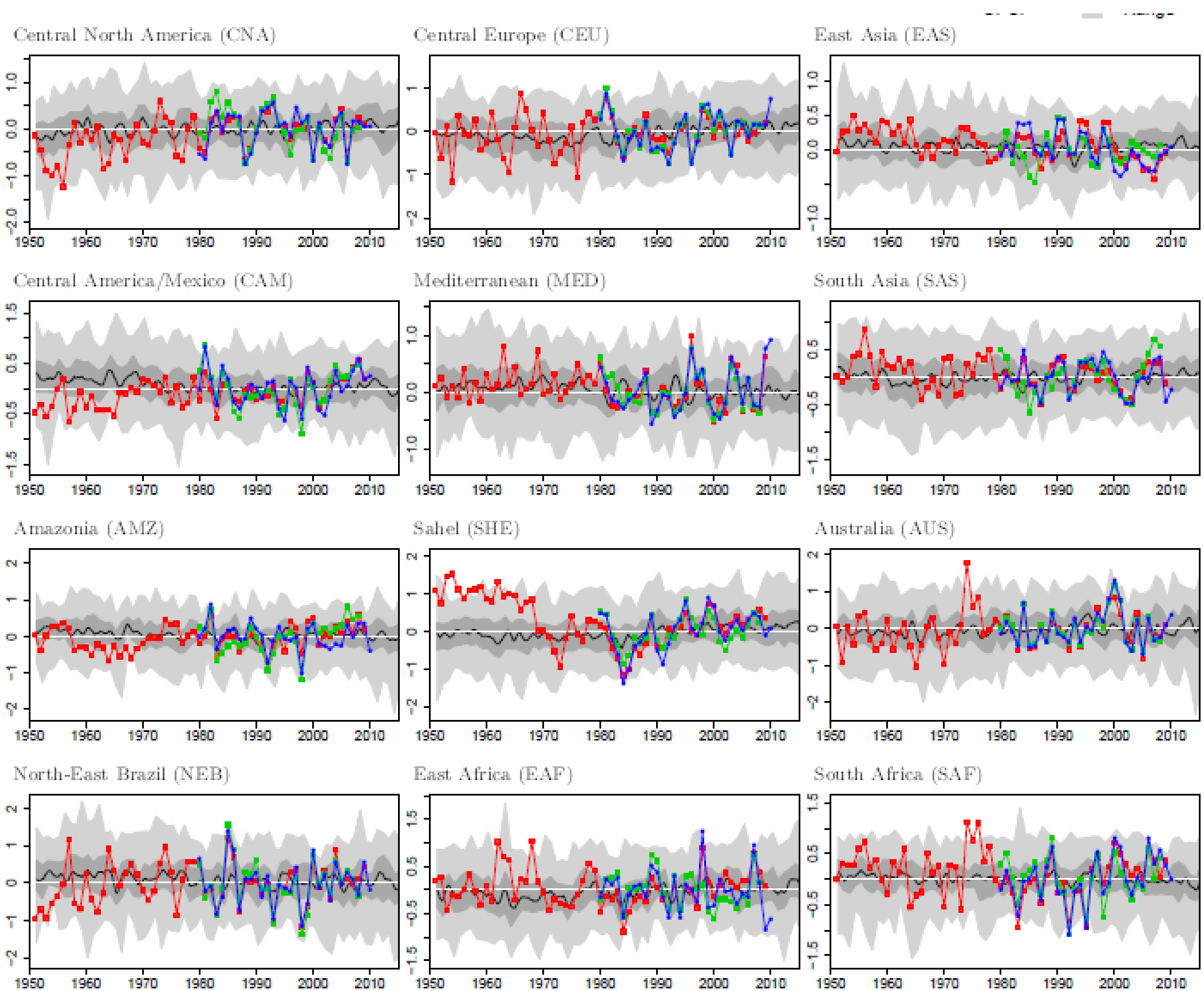
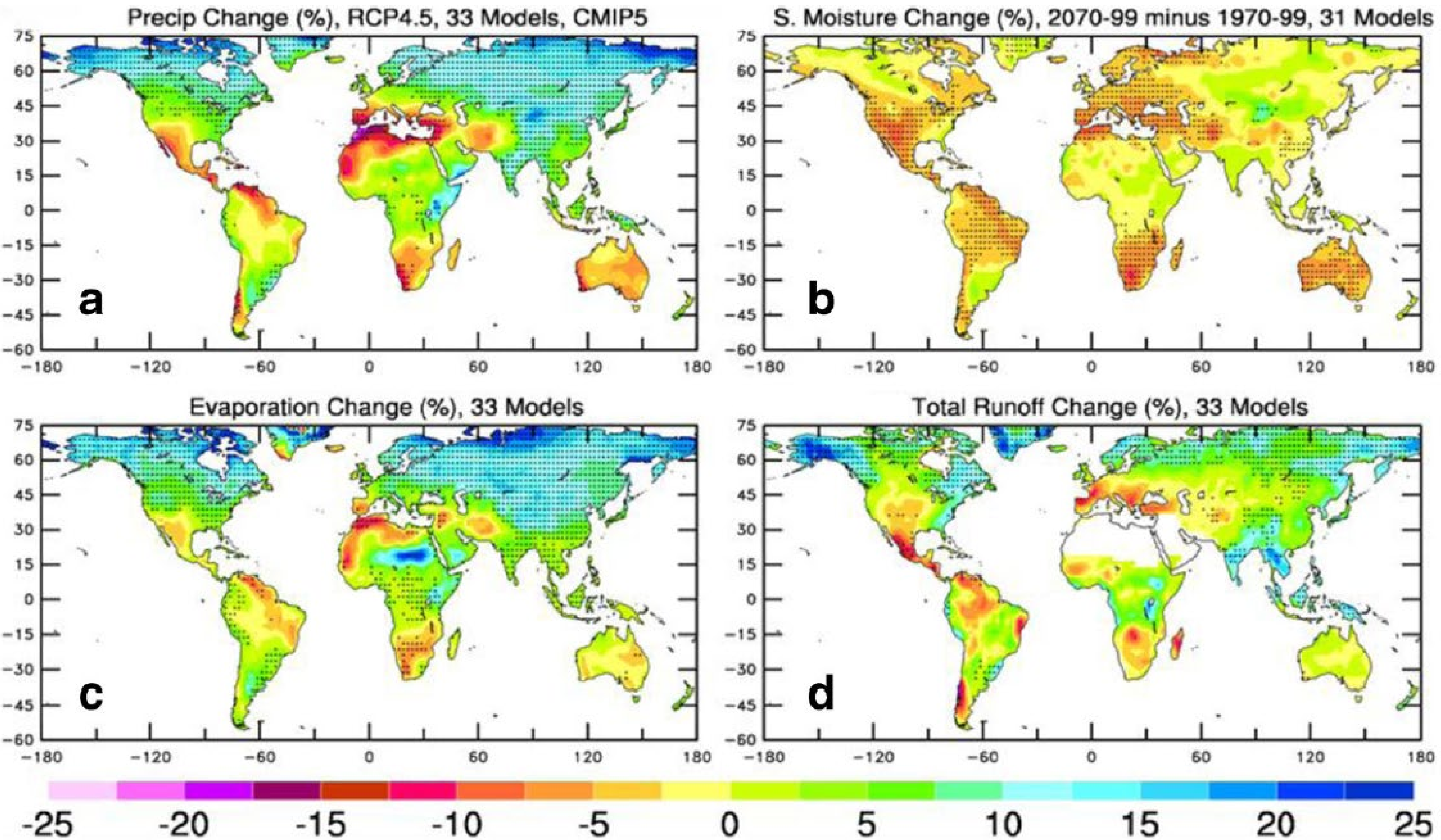
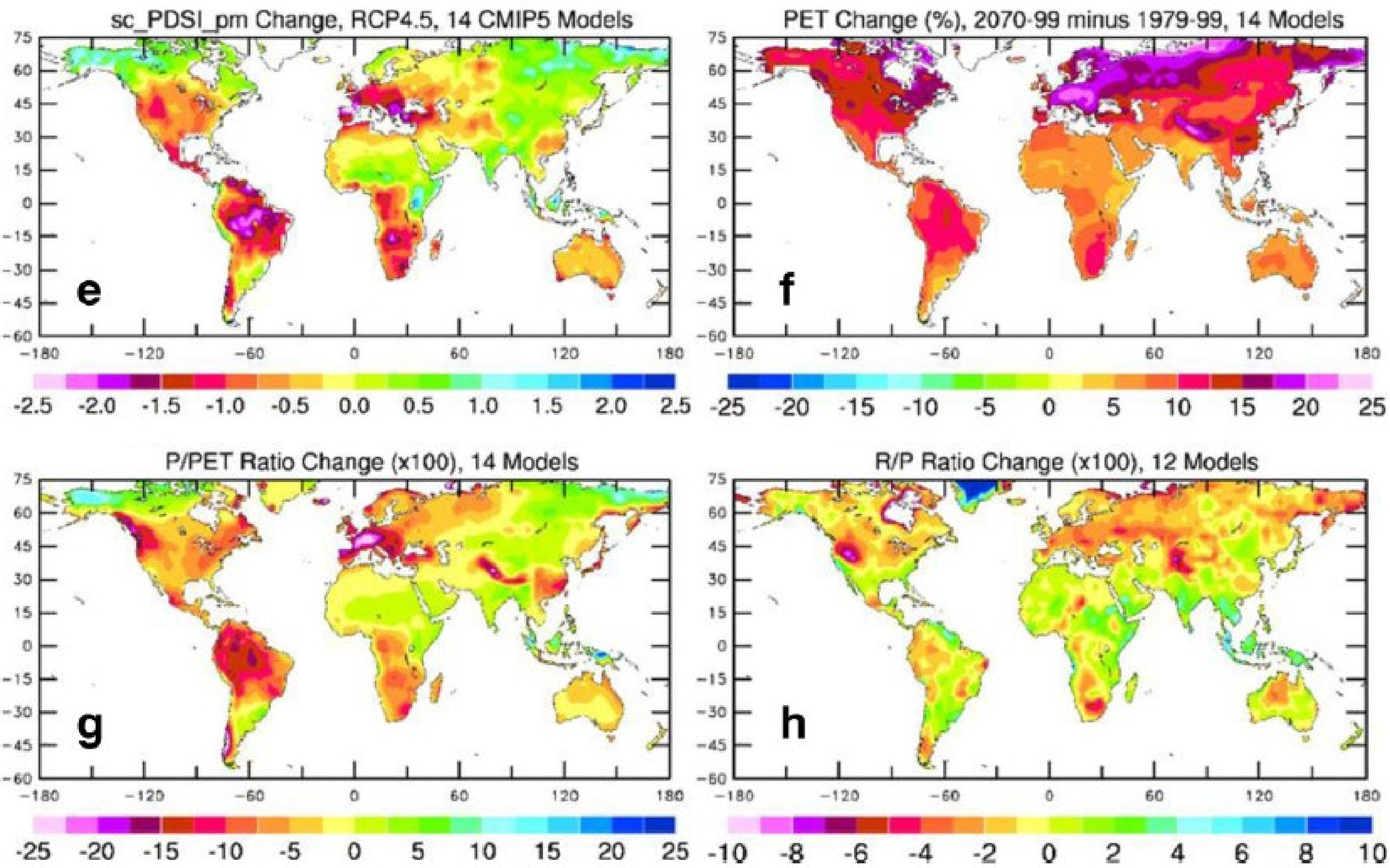
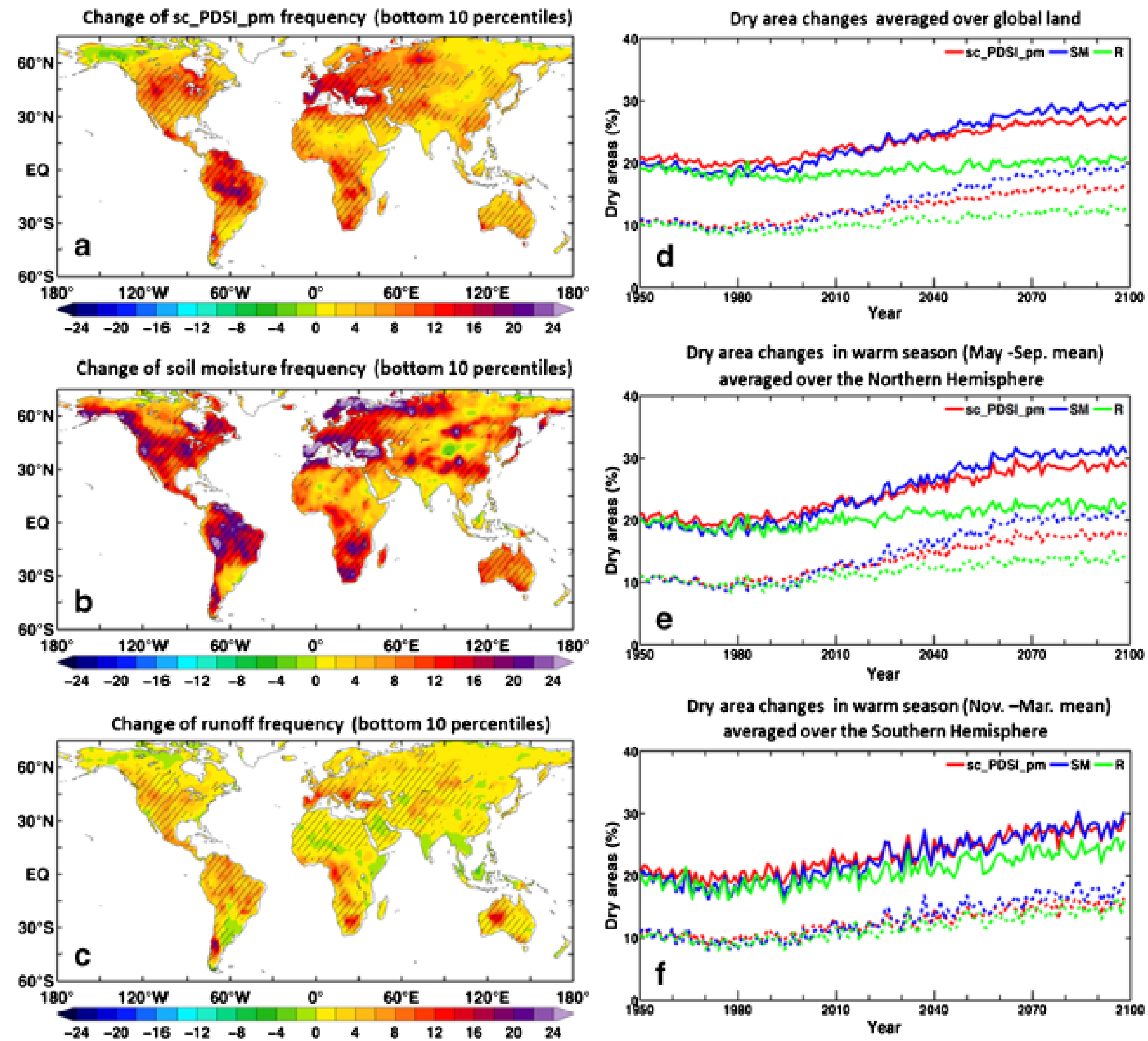


Fig. 3. Observation-based and CMIP5 simulated SPI12: annual averages of SPI12 values from three observation-based datasets (coloured lines) and median, inter-quartile range and total range across the CMIP5 ensemble (black line, dark grey and grey shading, respectively). Until 2005, CMIP5 data come from the historical simulations, after-wards, projections for the GHG concentrations scenario RCP8.5 are used. SPI12 values are calculated with respect to the 1979–2009 period for all datasets.

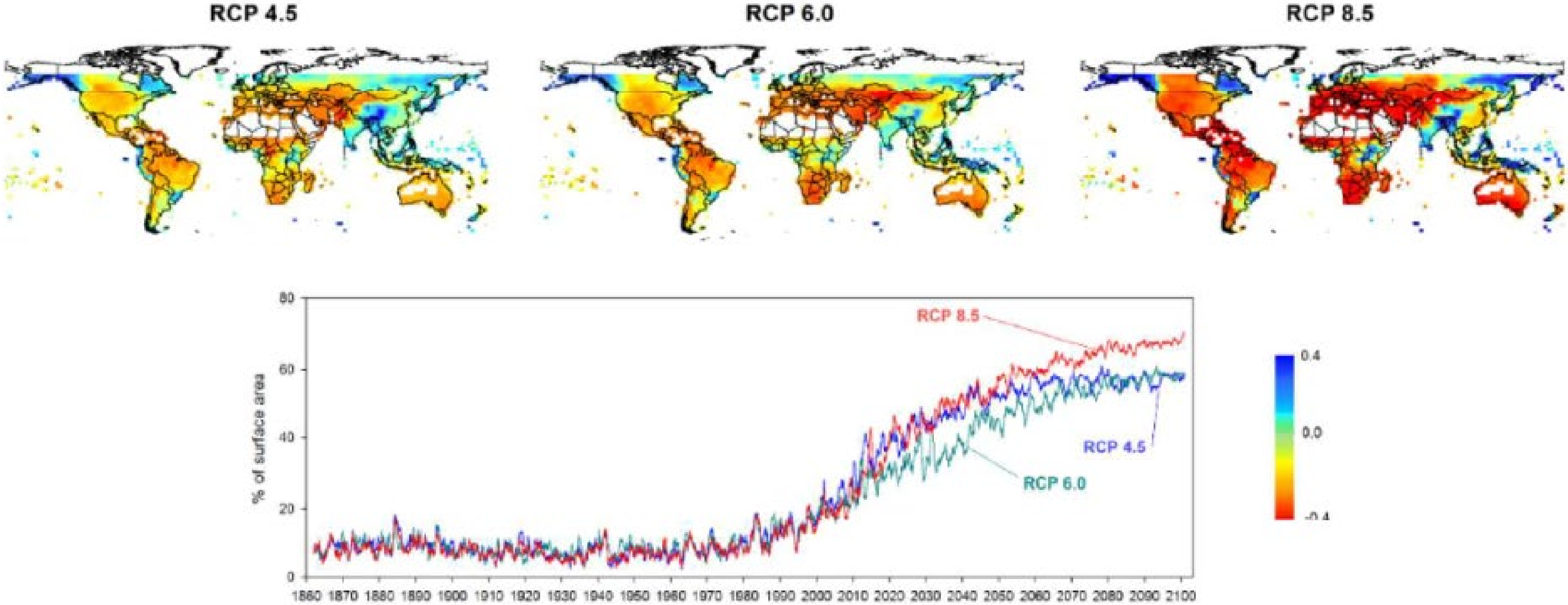


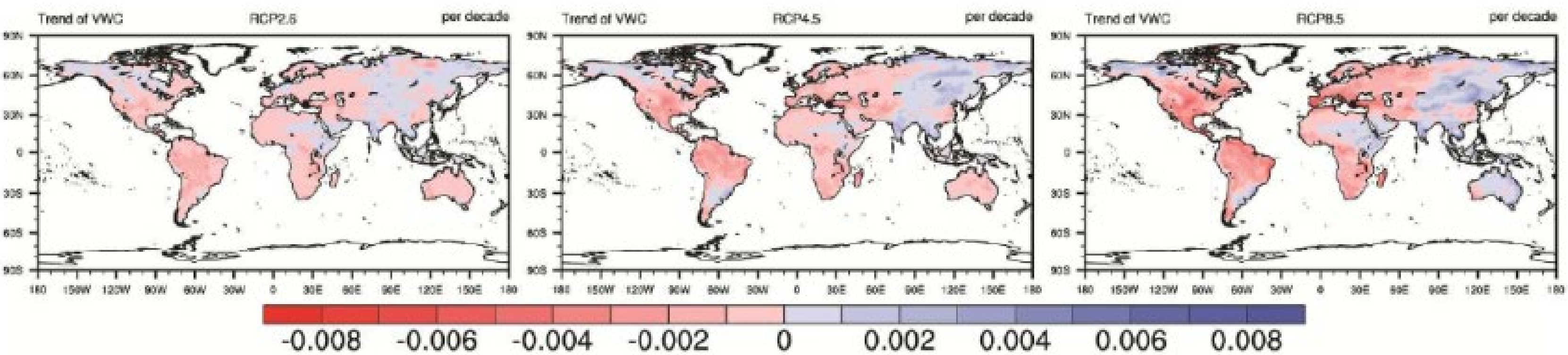
Precip Change (%), RCP4.5, 33 Models, CMIP5
a
S. Moisture Change (%), 2070-99 minus 1970-99, 31 Models
b
Evaporation Change (%), 33 Models
c
Total Runoff Change (%), 33 Models
d
75 60 45 30 15 0 -15 -30 -45 -60
-180 -120 -60 0 60 120 180
-25 -20 -15 -10 -5 0 5 10 15 20 25


sc_PDSI_pm Change, RCP4.5, 14 CMIP5 Models
e
-2.5 -2.0 -1.5 -1.0 -0.5 0.0 0.5 1.0 1.5 2.0 2.5
PET Change (%), 2070-99 minus 1979-99, 14 Models
f
-25 -20 -15 -10 -5 0 5 10 15 20 25
P/PET Ratio Change (x100), 14 Models
g
-25 -20 -15 -10 -5 0 5 10 15 20 25
R/P Ratio Change (x100), 12 Models
h
-10 -8 -6 -4 -2 0 2 4 6 8 10



Change of sc_PDSI_pm frequency (bottom 10 percentiles)
60°N
30°N
EQ
30°S
60°S
a
180°
120°W
60°W
0°
60°E
120°E
180°
-24 -20 -16 -12 -8 -4 0 4 8 12 16 20 24
Dry area changes averaged over global land
sc_PDSI_pm
SM
R
Dry areas (%)
Year
1950 1980 2010 2040 2070 2100
0 10 20 30 40
d
Change of soil moisture frequency (bottom 10 percentiles)
b
Dry area changes in warm season (May -Sep. mean)
averaged over the Northern Hemisphere
e
Change of runoff frequency (bottom 10 percentiles)
c
Dry area changes in warm season (Nov. –Mar. mean)
averaged over the Southern Hemisphere
f


RCP 4.5
RCP 6.0
RCP 8.5
% of surface area
80
60
40
20
0
1860 1870 1880 1890 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010 2020 2030 2040 2050 2060 2070 2080 2090 2100
RCP 8.5
RCP 4.5
RCP 6.0
0.4
0.0


Trend of VWC
RCP2.6
per decade
Trend of VWC
RCP4.5
per decade
Trend of VWC
RCP8.5
per decade
-0.008
-0.006
-0.004
-0.002
0
0.002
0.004
0.006
0.008

PROYECCIONES FUTURAS

AGU PUBLICATIONS

JGR

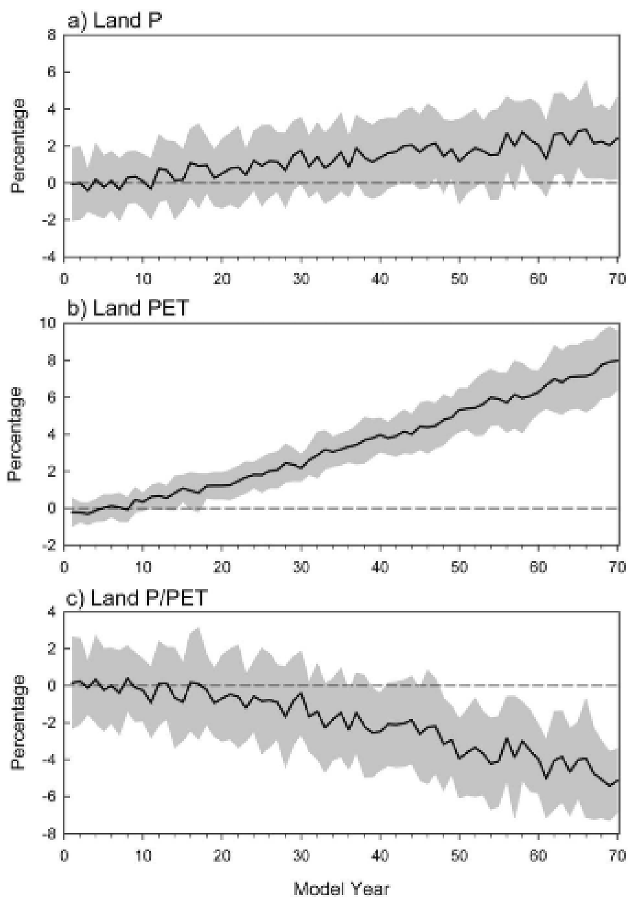
Journal of Geophysical Research: Atmospheres

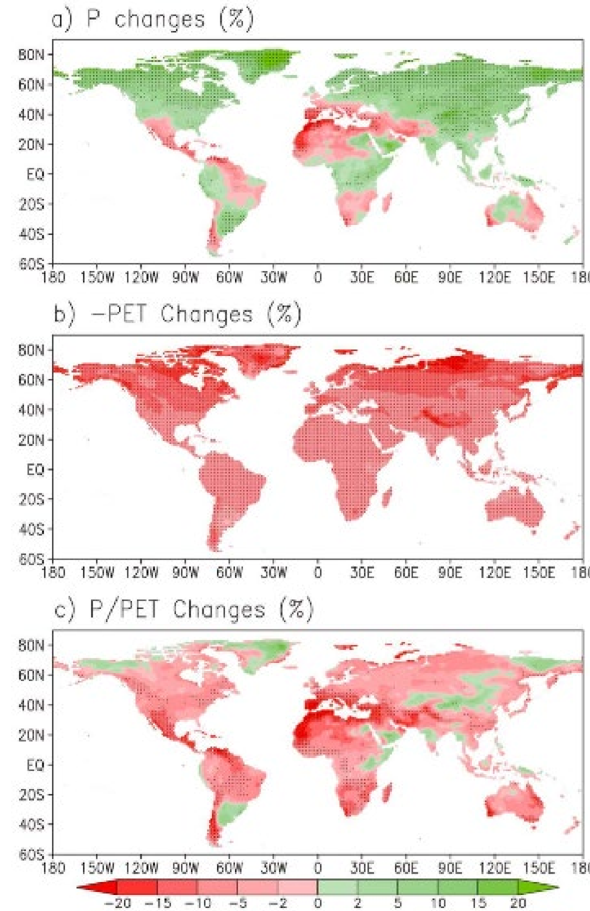
RESEARCH ARTICLE

10.1002/2014JD021608

Responses of terrestrial aridity to global warming

Qiang Fu[1,2] and Song Feng[3]





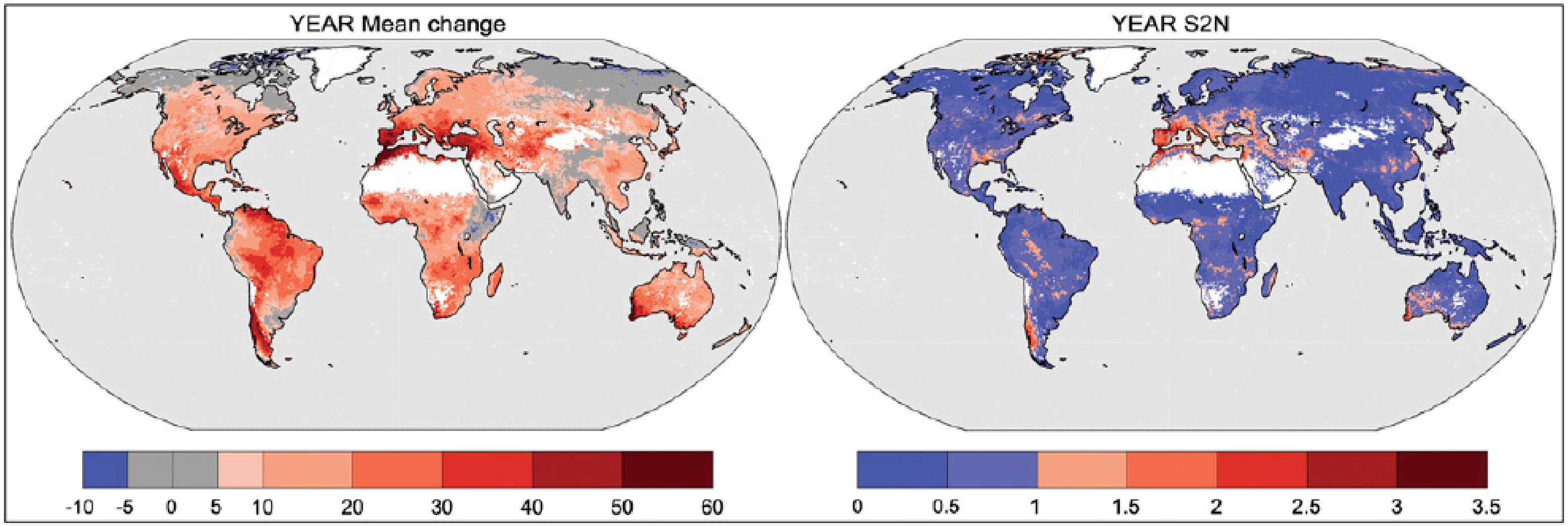
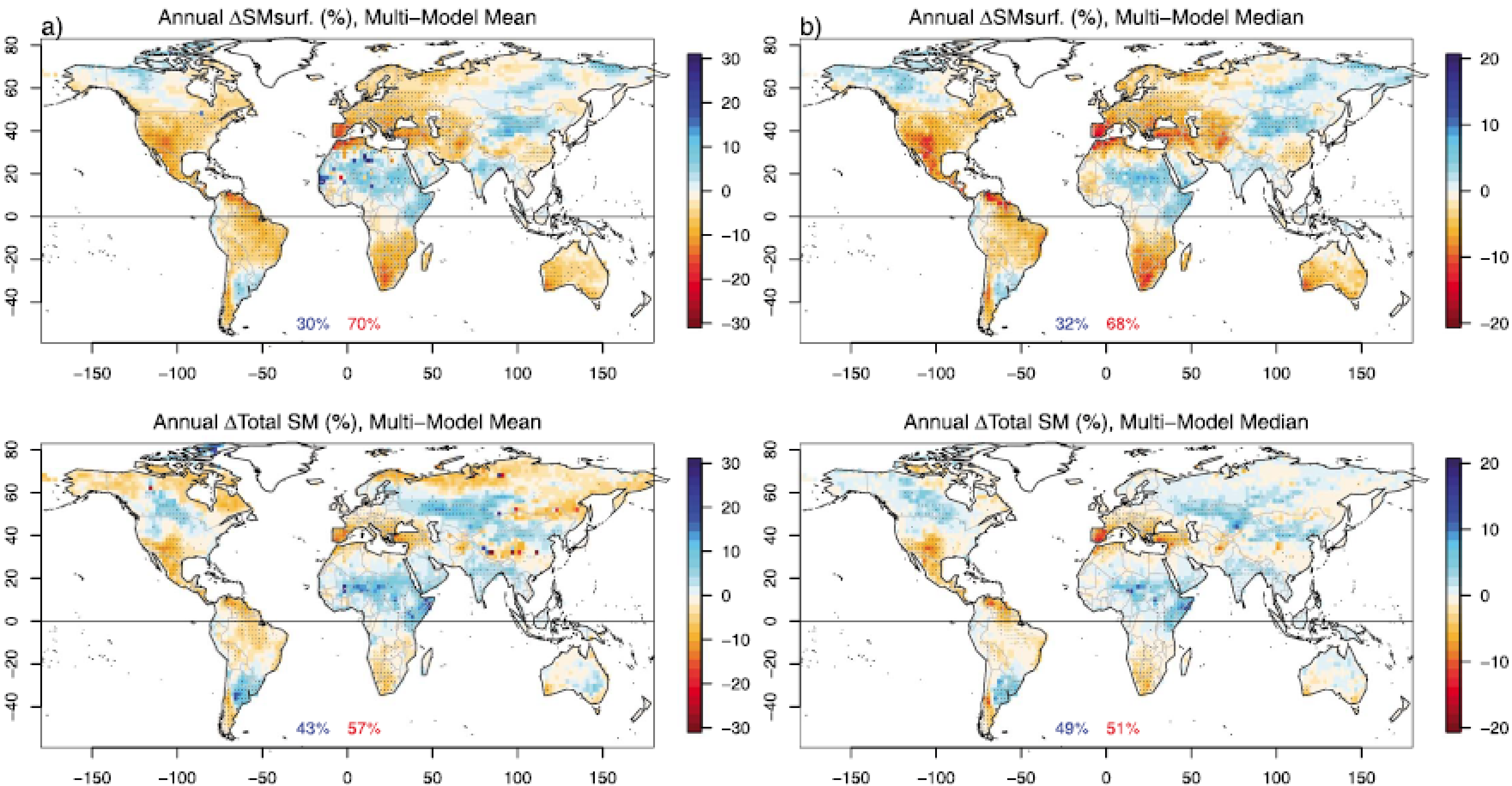
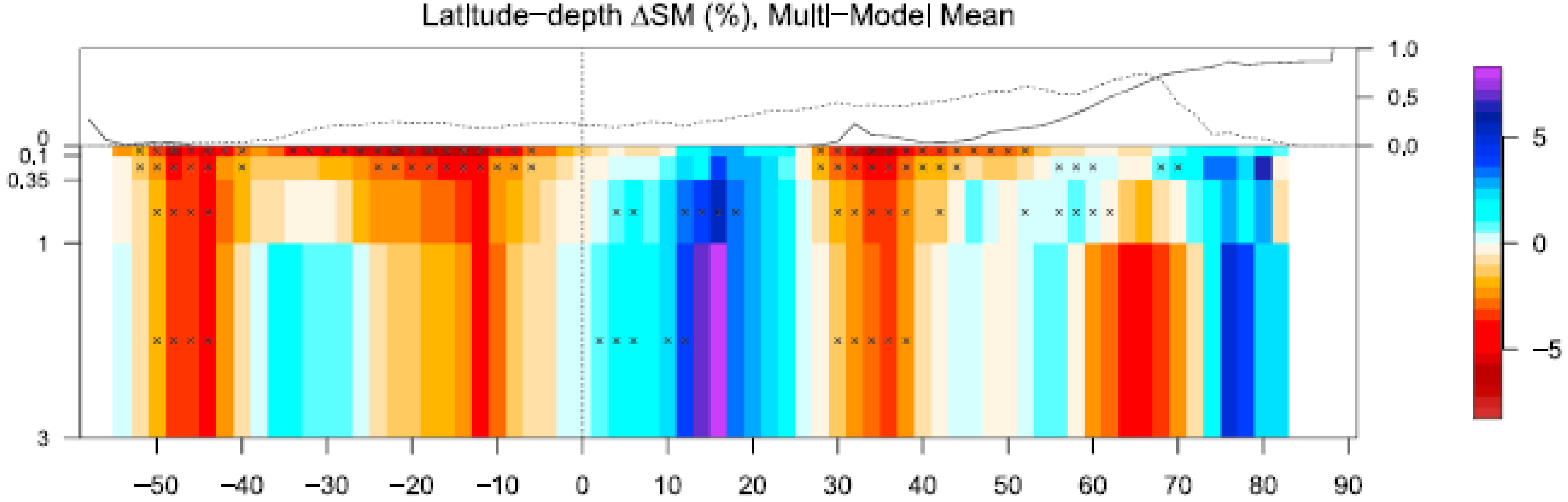


Fig. 1. Percentage change in the occurrence of days under drought conditions for the period 2070–2099 relative to 1976–2005, based on a multimodel ensemble MME experiment under RCP8.5 from five global climate models and seven global impact models: MME Mean change (*Left*) and associated signal-to-noise ratio (S2N, MME mean change divided by its inter-quartile range, *Right*). See *Methods* for definition of drought, S2N, and masking procedure.


a)
Annual ΔSMsurf. (%), Multi−Model Mean
30%
70%
b)
Annual ΔSMsurf. (%), Multi−Model Median
32%
68%
Annual ΔTotal SM (%), Multi−Model Mean
43%
57%
Annual ΔTotal SM (%), Multi−Model Median
49%
51%



Latitude−depth ΔSM (%), Multi−Model Mean
0
0,1
0,35
1
3
−50
−40
−30
−20
−10
0
10
20
30
40
50
60
70
80
90
1,0
0,5
0,0
5
0
−5

AGU PUBLICATIONS

Water Resources Research

RESEARCH ARTICLE

10.1002/2015WR017031

On the assessment of aridity with changes in atmospheric CO_2

Michael L. Roderick[1,2,3], Peter Greve[4], and Graham D. Farquhar[2,3]

4.1. A Flux-Based Approach for Assessing Changes in Aridity

We begin with the usual water balance equation,

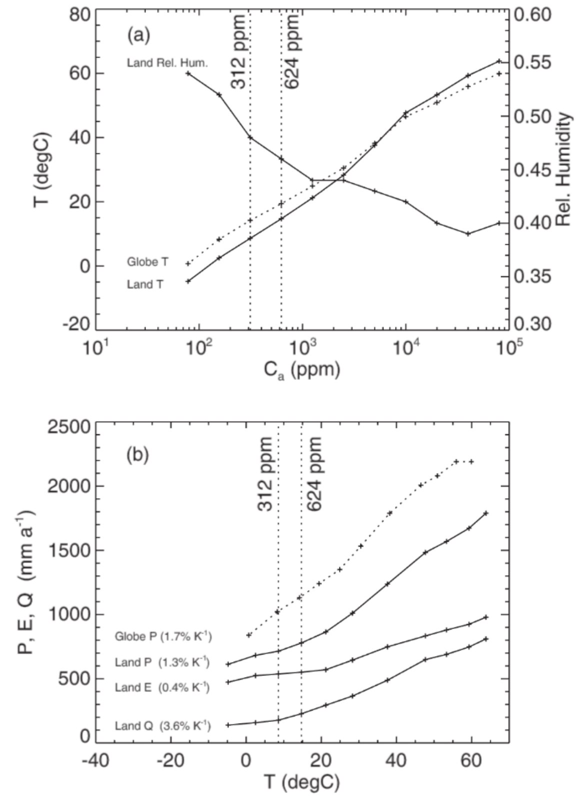
$$\frac{dS}{dt} = P - (E_t + E_s) - Q, \quad (2)$$

where the rate of change in water storage (dS/dt) is determined by inputs of precipitation (P) and outputs of evaporation (E) and runoff (Q). The total E is separated into two components, (i) transpiration (E_t) and (ii) a residual term that includes all other sources of evaporation (E_s). Note that E_s includes fluxes such as evapo-

$$W = \frac{A}{E_t},$$

the steady state water balance can be rewritten as,

$$P \approx \frac{A}{W} + E_s + Q.$$

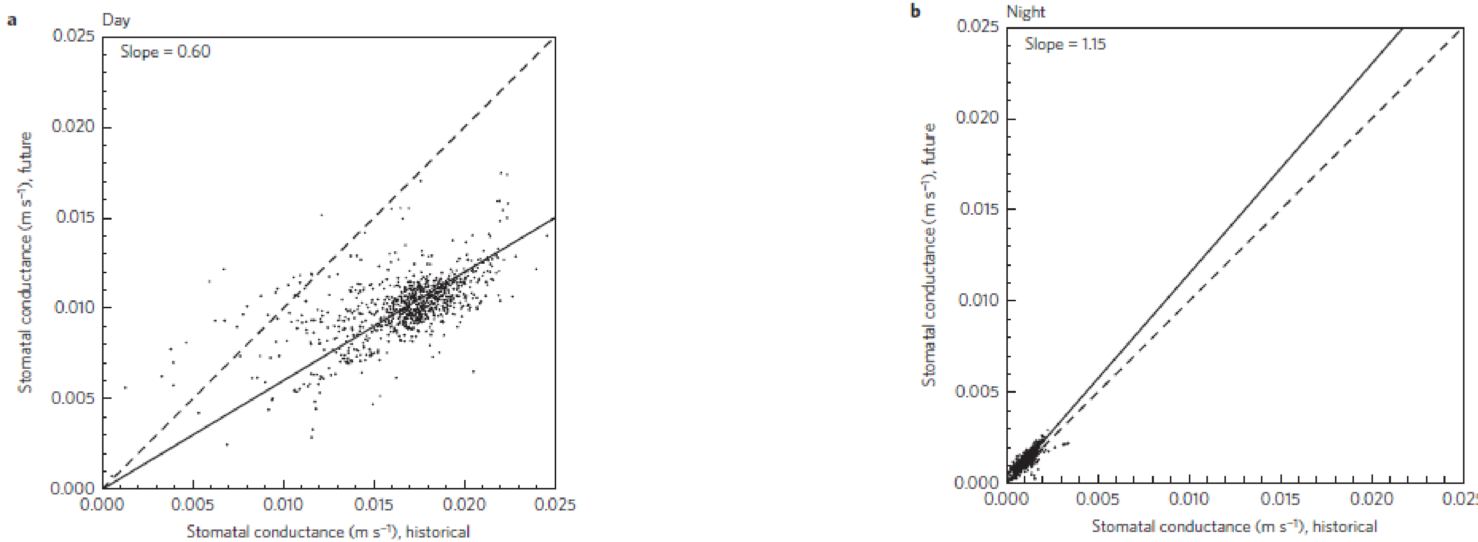


Current Climate Change Reports (2018) 4:202–209
https://doi.org/10.1007/s40641-018-0094-1

CLIMATE CHANGE AND DROUGHT (Q FU, SECTION EDITOR)

Drought Indices, Drought Impacts, CO_2, and Warming: a Historical and Geologic Perspective

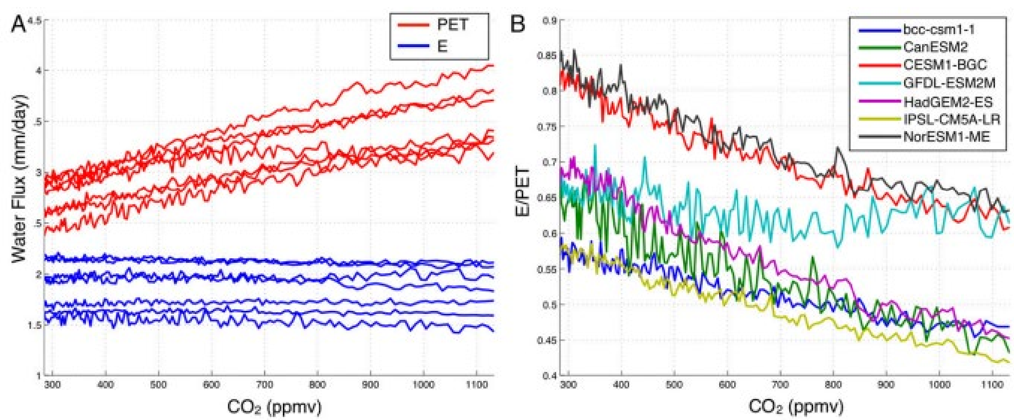
Jacob Scheff[1]

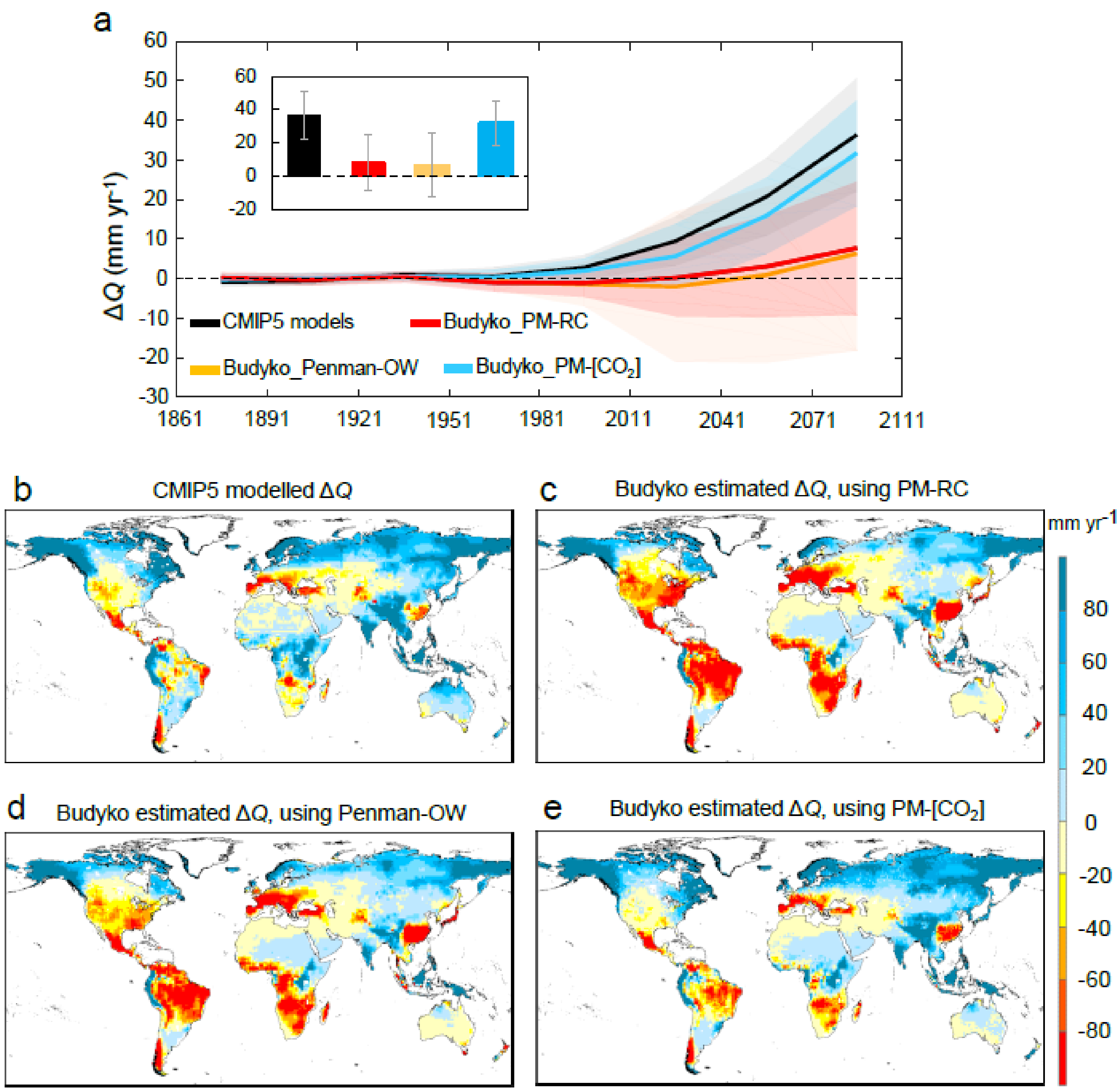


Plant responses to increasing CO_2 reduce estimates of climate impacts on drought severity

Abigail L. S. Swann[a,b,1], Forrest M. Hoffman[c,d], Charles D. Koven[e], and James T. Randerson[f]

[a]Department of Atmospheric Sciences, University of Washington, Seattle, WA 98195; [b]Department of Biology, University of Washington, Seattle, WA 98195; [c]Computer Science & Mathematics Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831; [d]Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831; [e]Climate & Ecosystem Sciences Division, Lawrence Berkeley National Laboratory, Berkeley, CA 94720; and [f]Department of Earth System Science, University of California, Irvine, CA 92697





a
ΔQ (mm yr-1)
CMIP5 models
Budyko_PM-RC
Budyko_Penman-OW
Budyko_PM-[CO2]
1861 1891 1921 1951 1981 2011 2041 2071 2111
b CMIP5 modelled ΔQ
c Budyko estimated ΔQ, using PM-RC
d Budyko estimated ΔQ, using Penman-OW
e Budyko estimated ΔQ, using PM-[CO2]
mm yr-1
80 60 40 20 0 -20 -40 -60 -80

esa ECOSPHERE

ESA CENTENNIAL PAPER

On underestimation of global vulnerability to tree mortality and forest die-off from hotter drought in the Anthropocene

Craig D. Allen,[1,†] David D. Breshears,[2] and Nate G. McDowell[3]

[1]U.S. Geological Survey, Fort Collins Science Center, Jemez Mountains Field Station, Los Alamos, New Mexico 87544 USA
[2]School of Natural Resources and the Environment, joint with the Department of Ecology and Evolutionary Biology, University of Arizona, Tucson, Arizona 85745 USA
[3]Earth and Environmental Science Division, MS-J495, Los Alamos National Laboratory, Los Alamos, New Mexico 85745 USA

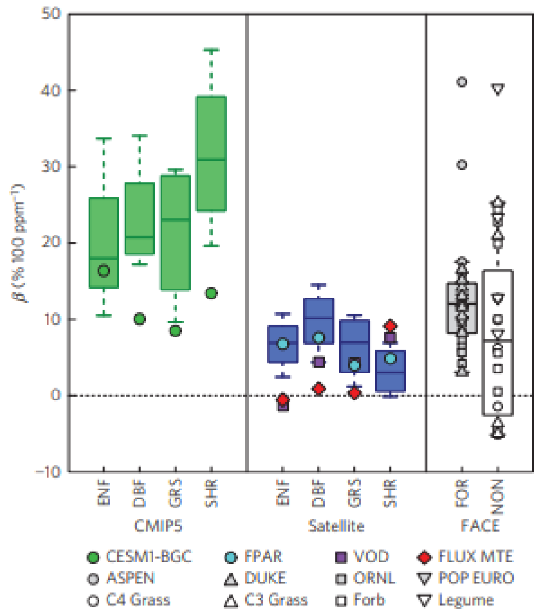
3. CO_2 Fertilization & WUE

Sufficient to compensate. CO_2 fertilization and water-use efficiency effects generally compensate for drought and heat stress, fostering increased tree growth and NPP, widespread woody plant expansion in dryland ecosystems, and an overall "greening" observed in many regions.	**Effects limited; no benefit during severe drought.** Mortality processes associated with growing drought and heat stress already are overcoming CO_2 fertilization and water-use efficiency buffering at times and across extensive regions, with forest "browning" and NPP declines, reductions in forest growth, and markedly greater tree mortality observed in multiple regions of growing water stress in recent decades despite concurrent rising [CO_2].

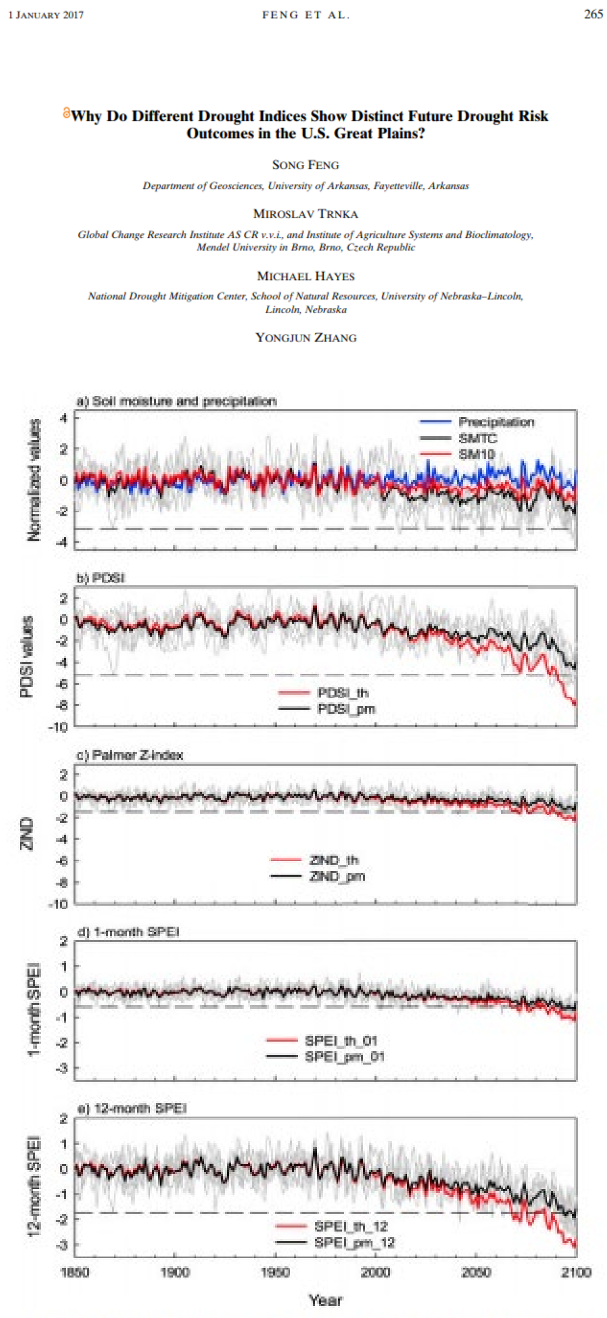
LETTERS
PUBLISHED ONLINE: 7 DECEMBER 2015 | DOI: 10.1038/NCLIMATE2879
nature climate change

Large divergence of satellite and Earth system model estimates of global terrestrial CO_2 fertilization

W. Kolby Smith[1,2]*, Sasha C. Reed[3], Cory C. Cleveland[1], Ashley P. Ballantyne[1], William R. L. Anderegg[4], William R. Wieder[5,6], Yi Y. Liu[7] and Steven W. Running[1]



- Los modelos no consideran cambios en el tipo de vegetación y en el área foliar
- Efecto radiativo del CO_2 vs. Efecto en la fertilización



Why Do Different Drought Indices Show Distinct Future Drought Risk Outcomes in the U.S. Great Plains?

SONG FENG
Department of Geosciences, University of Arkansas, Fayetteville, Arkansas

MIROSLAV TRNKA
Global Change Research Institute AS CR v.v.i., and Institute of Agriculture Systems and Bioclimatology, Mendel University in Brno, Brno, Czech Republic

MICHAEL HAYES
National Drought Mitigation Center, School of Natural Resources, University of Nebraska–Lincoln, Lincoln, Nebraska

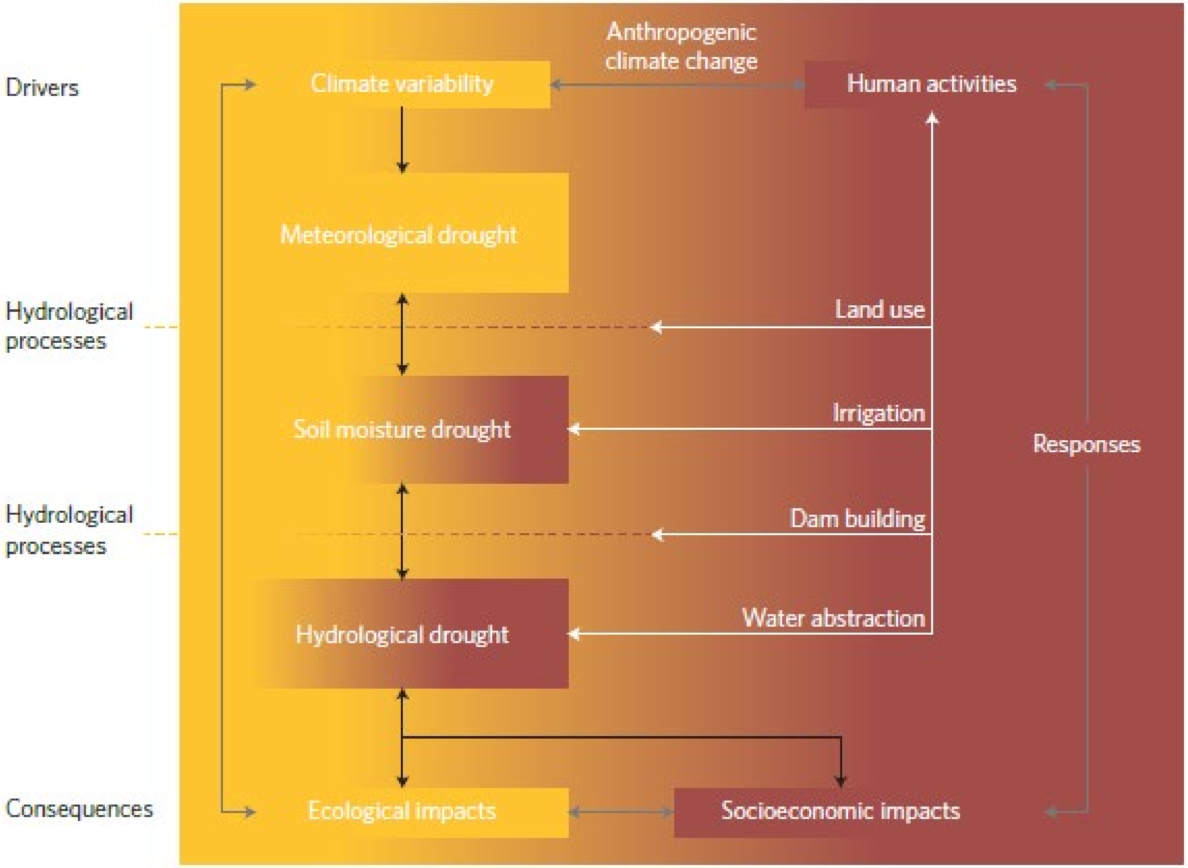
YONGJUN ZHANG

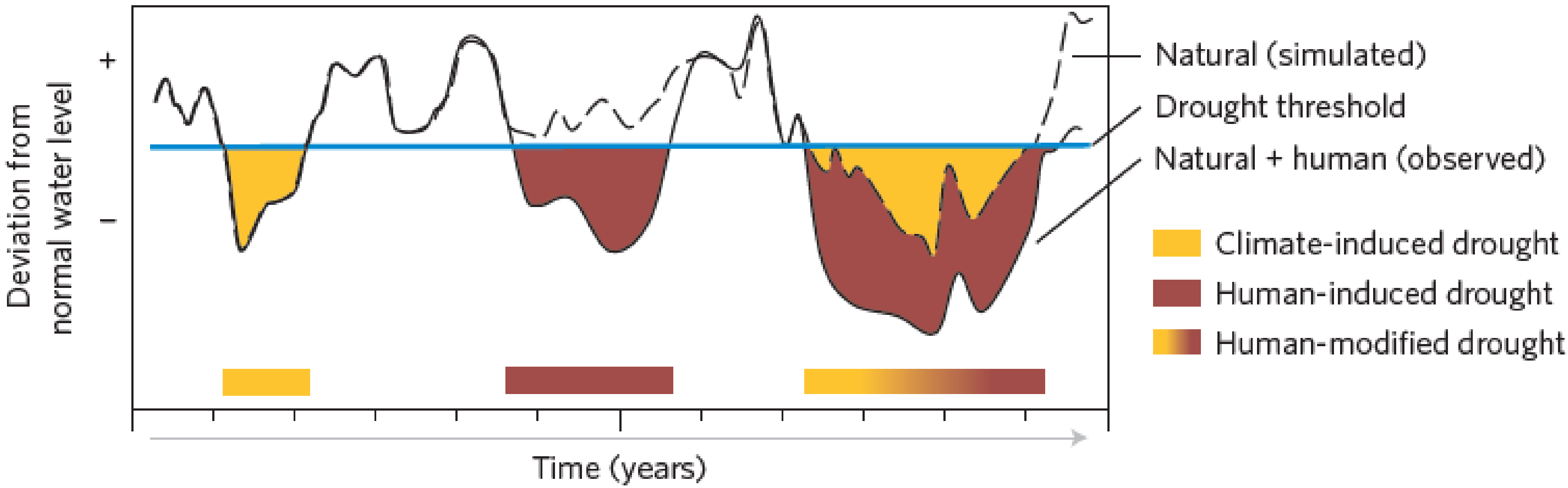
- **La clave es establecer diferencias entre regiones con déficit de humedad y aquellas excendentarias de humedad**
- **Y diferenciar entre sequías hidrológicas y agrícolas/ambientales**

Drought in the Anthropocene

Anne F. Van Loon, Tom Gleeson, Julian Clark, Albert I. J. M. Van Dijk, Kerstin Stahl, Jamie Hannaford, Giuliano Di Baldassarre, Adriaan J. Teuling, Lena M. Tallaksen, Remko Uijlenhoet, David M. Hannah, Justin Sheffield, Mark Svoboda, Boud Verbeiren, Thorsten Wagener, Sally Rangecroft, Niko Wanders and Henny A. J. Van Lanen

Drought management is inefficient because feedbacks between drought and people are not fully understood. In this human-influenced era, we need to rethink the concept of drought to include the human role in mitigating and enhancing drought.





Deviation from normal water level
+
–
Time (years)
Natural (simulated)
Drought threshold
Natural + human (observed)
Climate-induced drought
Human-induced drought
Human-modified drought

Contents lists available at ScienceDirect

Journal of Hydrology

journal homepage: www.elsevier.com/locate/jhydrol

Human and climate impacts on the 21st century hydrological drought

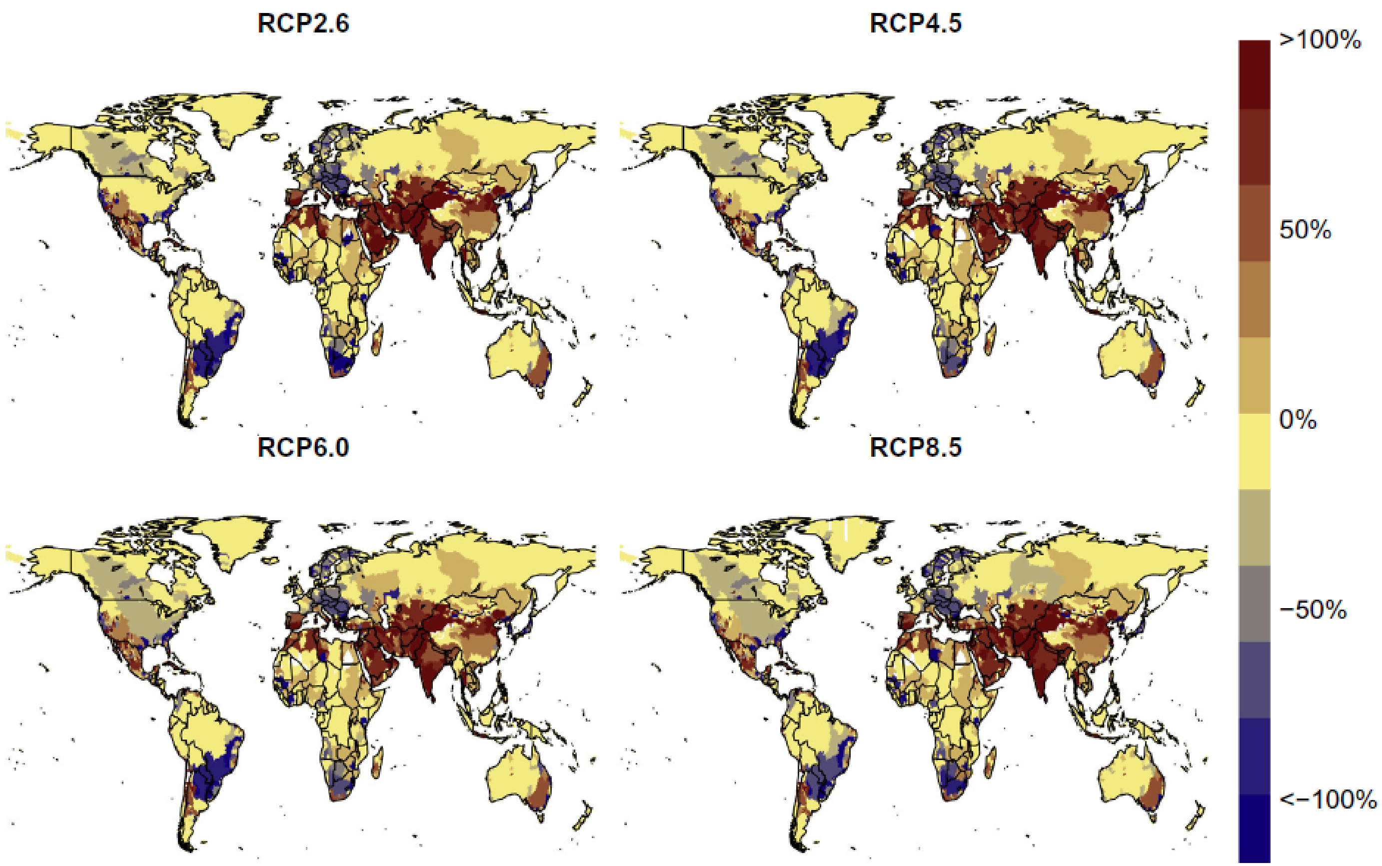


Fig. 5. Impact of reservoirs and human water use on drought deficit volume compared to the pristine conditions ($dDef_{human}$), over the period 2070–2099. Each plot gives the annual average impact derived from 5 GCMs for different RCP scenarios. Impact is calculated as a percent, where positive percentages indicate a increase in the drought deficit volume and negative percentages indicate an decrease in the drought deficit volume as a result of human water use and reservoirs.

¡Muchas gracias!