Tendencias y proyecciones futuras de tormentas y vientos extremos

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UNIVERSIDAD DE CANTABRIA

METEOROLOGY GROUP

Proyecciones Regionales de Cambio Climático Para Vientos Extremos en España Para el Siglo XXI

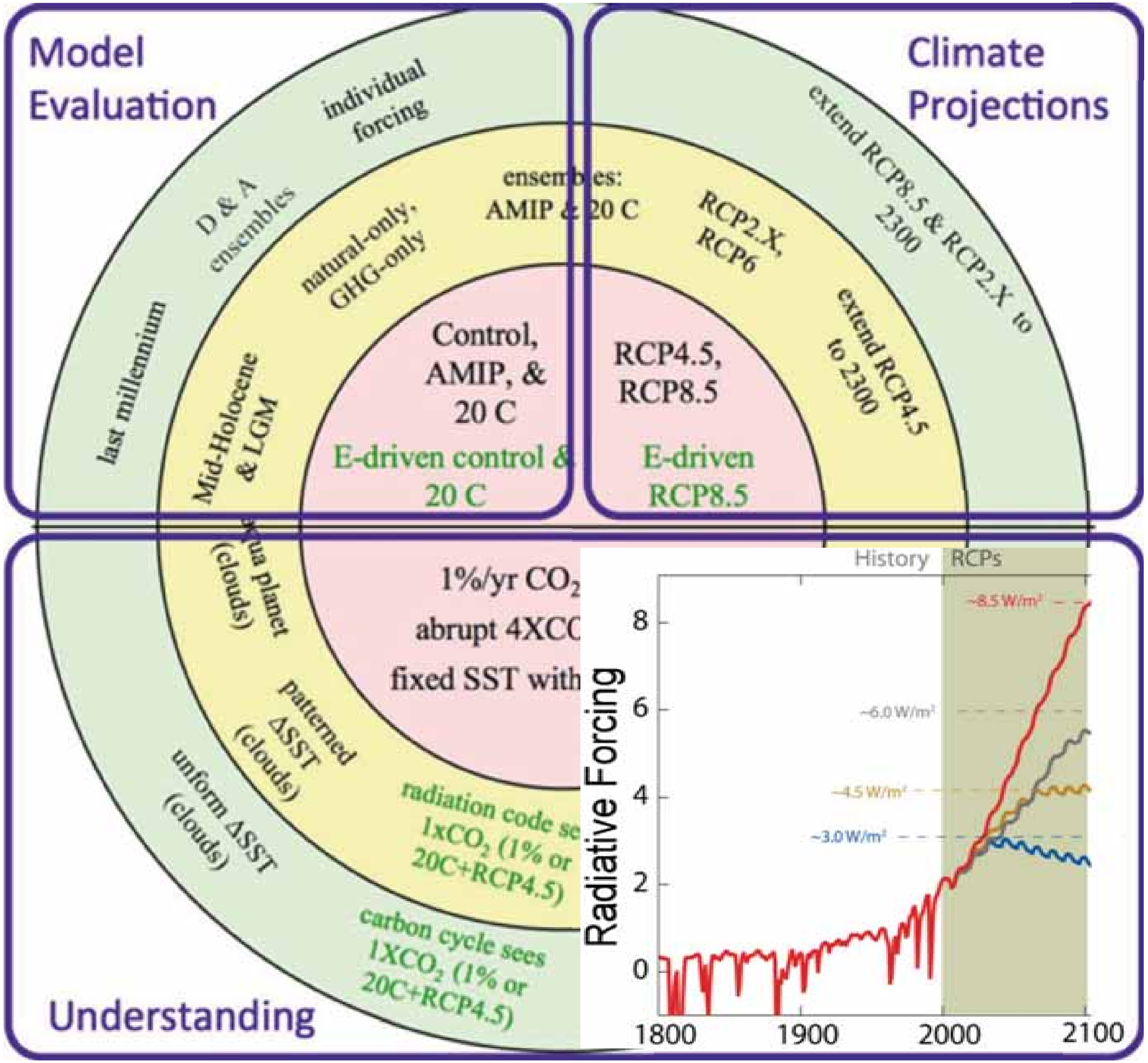
Julio 2017 - Junio 2018

Fundación Biodiversidad

GOBIERNO DE ESPAÑA

MINISTERIO DE AGRICULTURA, ALIMENTACIÓN Y MEDIO AMBIENTE

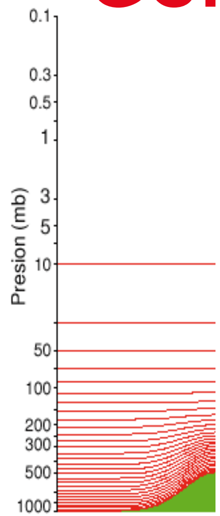
IPCC-AR5 / CMIP5

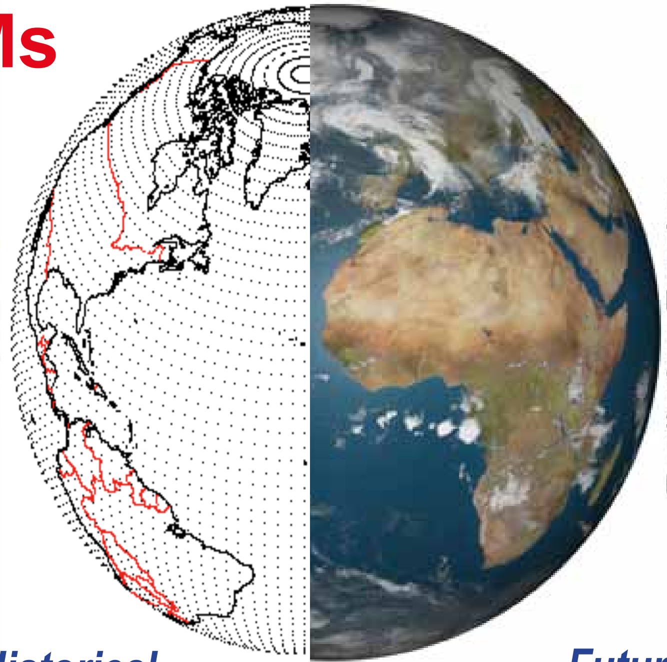


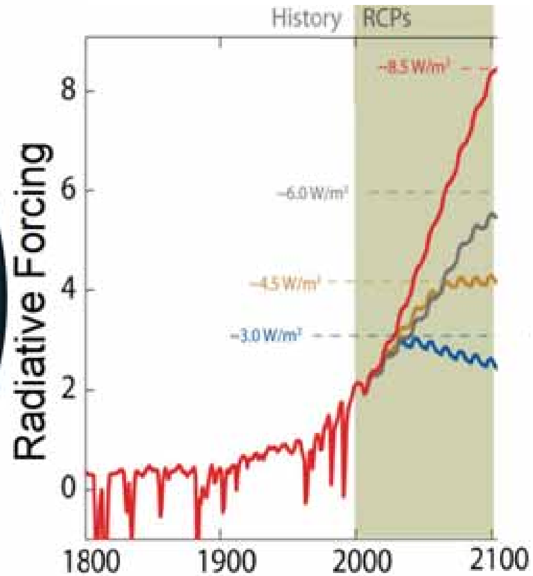
Multi-decadal forcing conditions are given for a number of historical and future scenarios for model validation and climate change attribution and projection.

Climate change projections

GCMs







Equations of conservation (mass,momentum,energy,water vapour) and gas state

$\boldsymbol{v}$ = (u, v, w), T, p, ρ = 1/α and q

$$
\begin{cases}
\dfrac{d\boldsymbol{v}}{dt} = -\alpha\nabla p - \nabla\phi + \boldsymbol{F} - 2\boldsymbol{\Omega}\times\boldsymbol{v} \\
\dfrac{\partial\rho}{\partial t} = -\nabla\cdot(\rho\,\boldsymbol{v}) \\
p\,\alpha = RT \\
Q = C_p\dfrac{dT}{dt} - \alpha\dfrac{dp}{dt} \\
\dfrac{\partial\rho\,q}{\partial t} = -\nabla\cdot(\rho\,\boldsymbol{v}\,q) + \rho(E - C)
\end{cases}
$$

Historical simulations

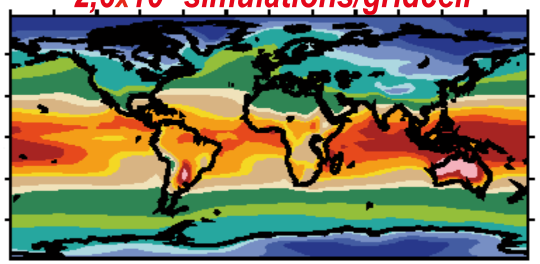
1980	1990	2000

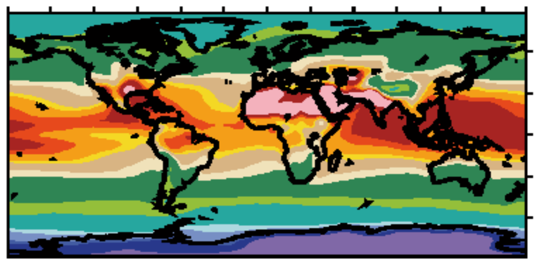
1h step x 30 years

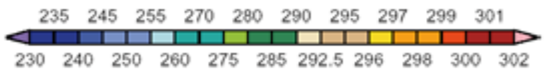
2,6x10^5 simulations/gridcell

Future projections (scenarios)

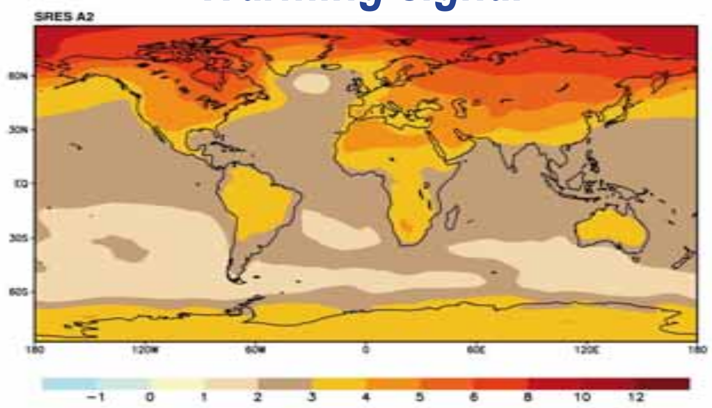
2010	2020	2030	2040	2050	2060	2070	2080	2090







"delta" method
Warming signal



Computational (and physical) constraints limit the resolution (~100-200 Km)

Multi-Model climate projections

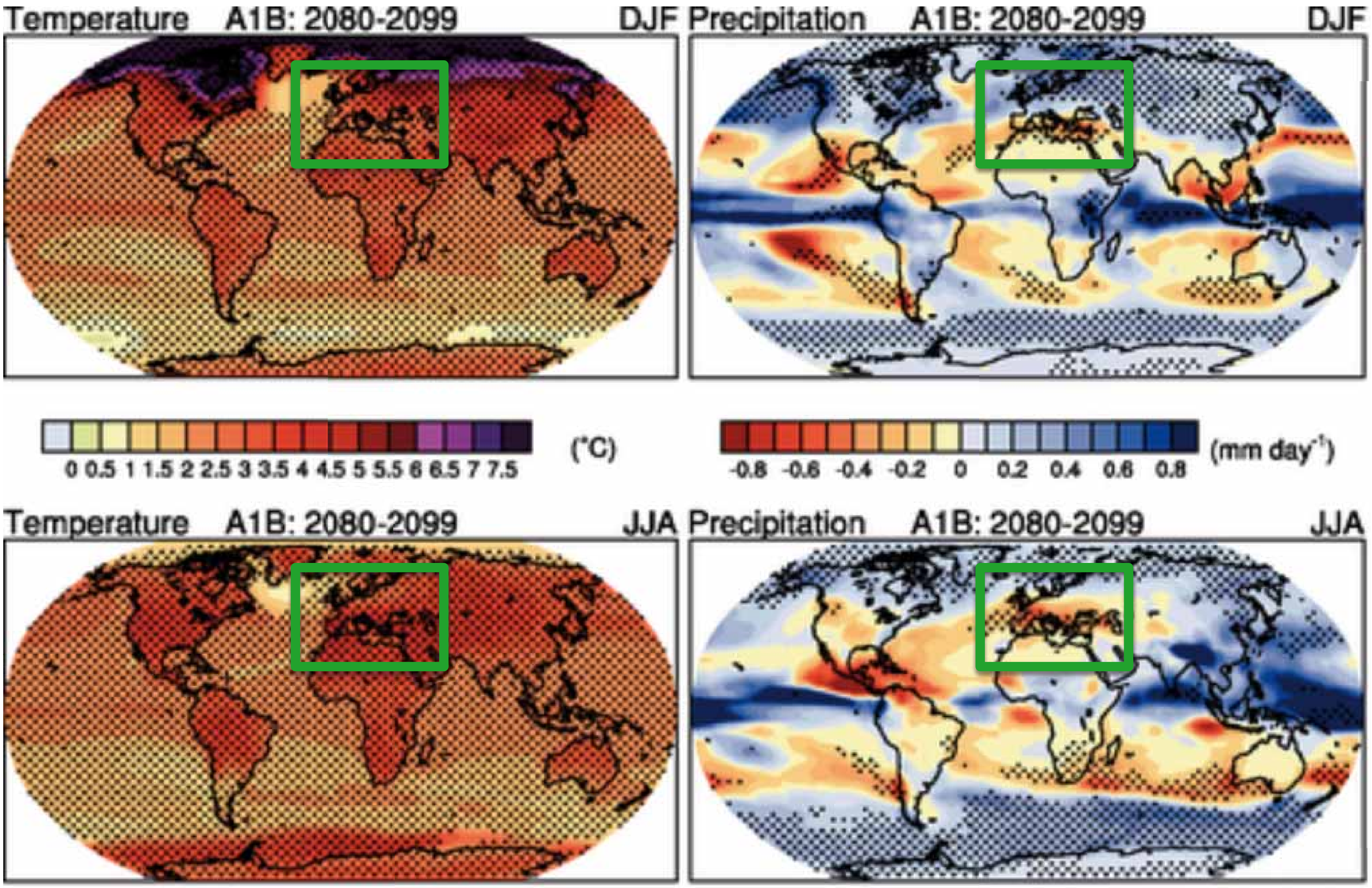
Climate Models	B
BCC-CSM1-1	0.97
CanESM2_esm	0.76
CanESM2	0.77
CCSM4	1.08
CESM1-BGC_esm	1.06
CESM1-CAM5	0.94
CESM1-WACCM	1.04
CNRM-CM5	0.90
CSIRO-ACCESS1-0	0.91
CSIRO-Mk3-6-0	0.93
FGOALS-g2	1.10
FGOALS-s2	0.83
GFDL-CM3	0.92
GFDL-ESM2G_esm	1.04
GFDL-ESM2M_esm	1.05
GFDL-ESM2M	1.06
GISS-E2-H	0.96
GISS-E2-R	0.96
HadGEM2-CC	0.88
HadGEM2-ES_esm	0.91
HadGEM2-ES	0.90
INMCM4_esm	0.93
IPSL-CM5A-LR_esm	0.77
IPSL-CM5A-LR	0.77
IPSL-CM5A-MR	0.79
IPSL-CM5B-LR	0.83
MIROC5	0.99
MIROC-ESM_esm	1.14
MIROC-ESM	1.17
MPI-ESM-LR_esm	1.15
MPI-ESM-P	0.88
MRI-CGCM3	0.88
MRI-ESM1_esm	0.84
NorESM1-M	0.85
Ensemble Mean	0.89
Ensemble Median	0.85

$$B = \frac{\sum_{i=1}^{n} P_{CMIP5}}{\sum_{i=1}^{n} P_{GPCP}}$$

[a]Optimal values of these metrics are all equal to 1.

Climate change projections are based on consensus multi-model information.

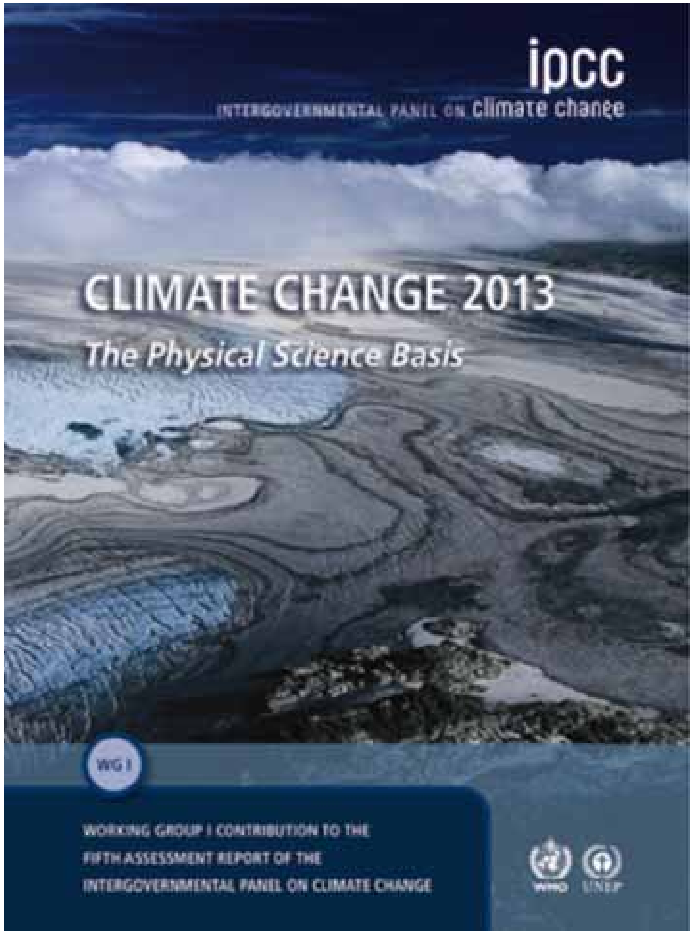
Multi-Model climate projections



Wind in IPCC Reports

The different IPCC Assessment Reports provide no information on future wind projections, only inconclusive information on past trends.

IPCC-AR5 CMIP5 **(2013)**



Wind in IPCC Reports

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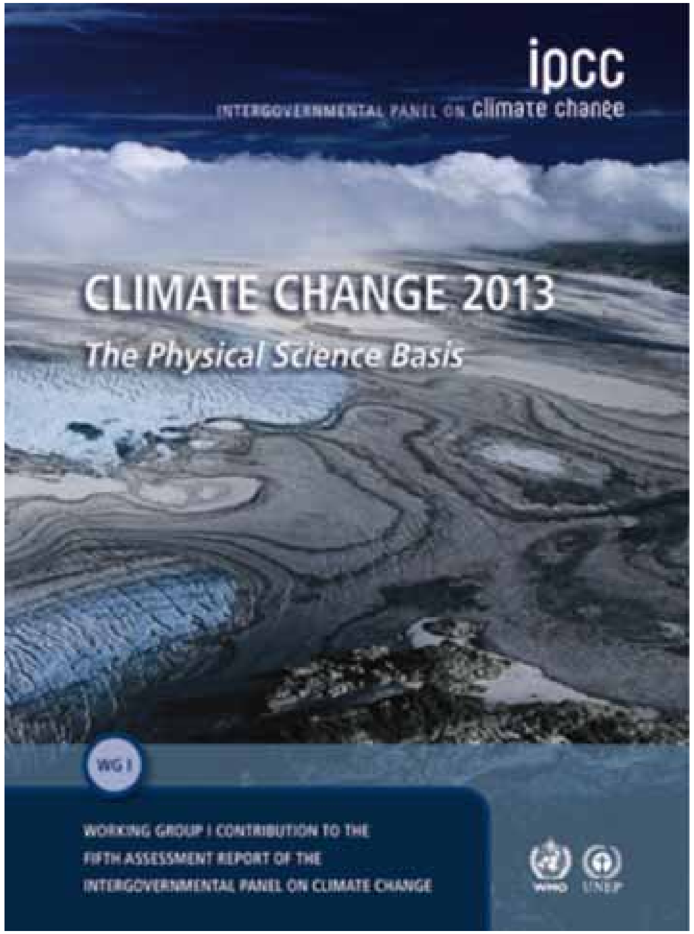
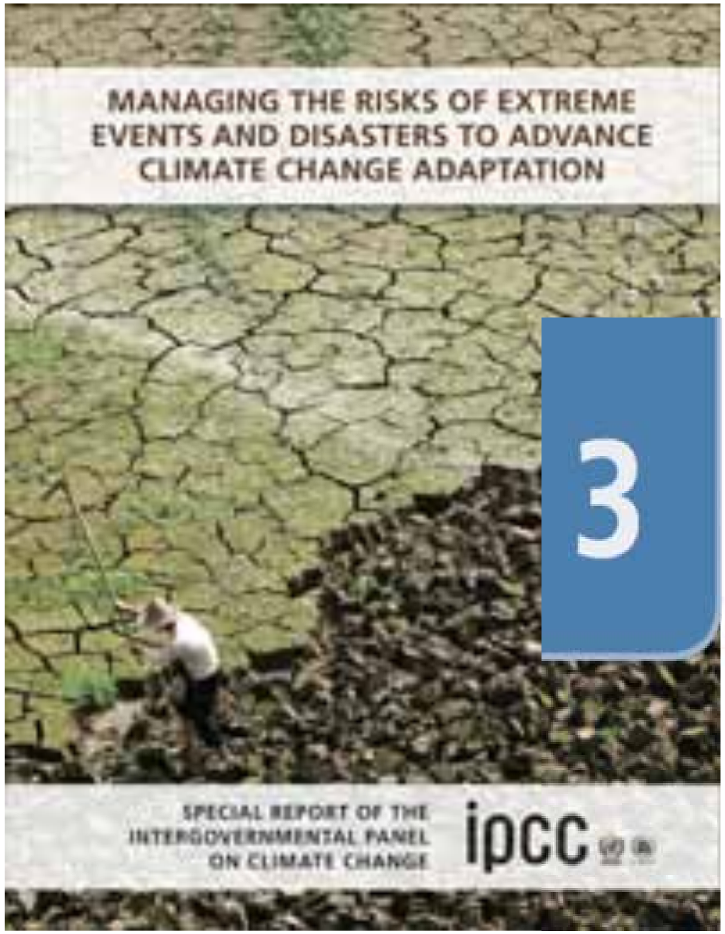
IPCC-AR5 CMIP5 **(2013)** **SRES** Special Rep. (2012)





The IPCC special report on climate extremes discussed the existing information on mean and extreme wind projections, obtaining also inconclusive results.

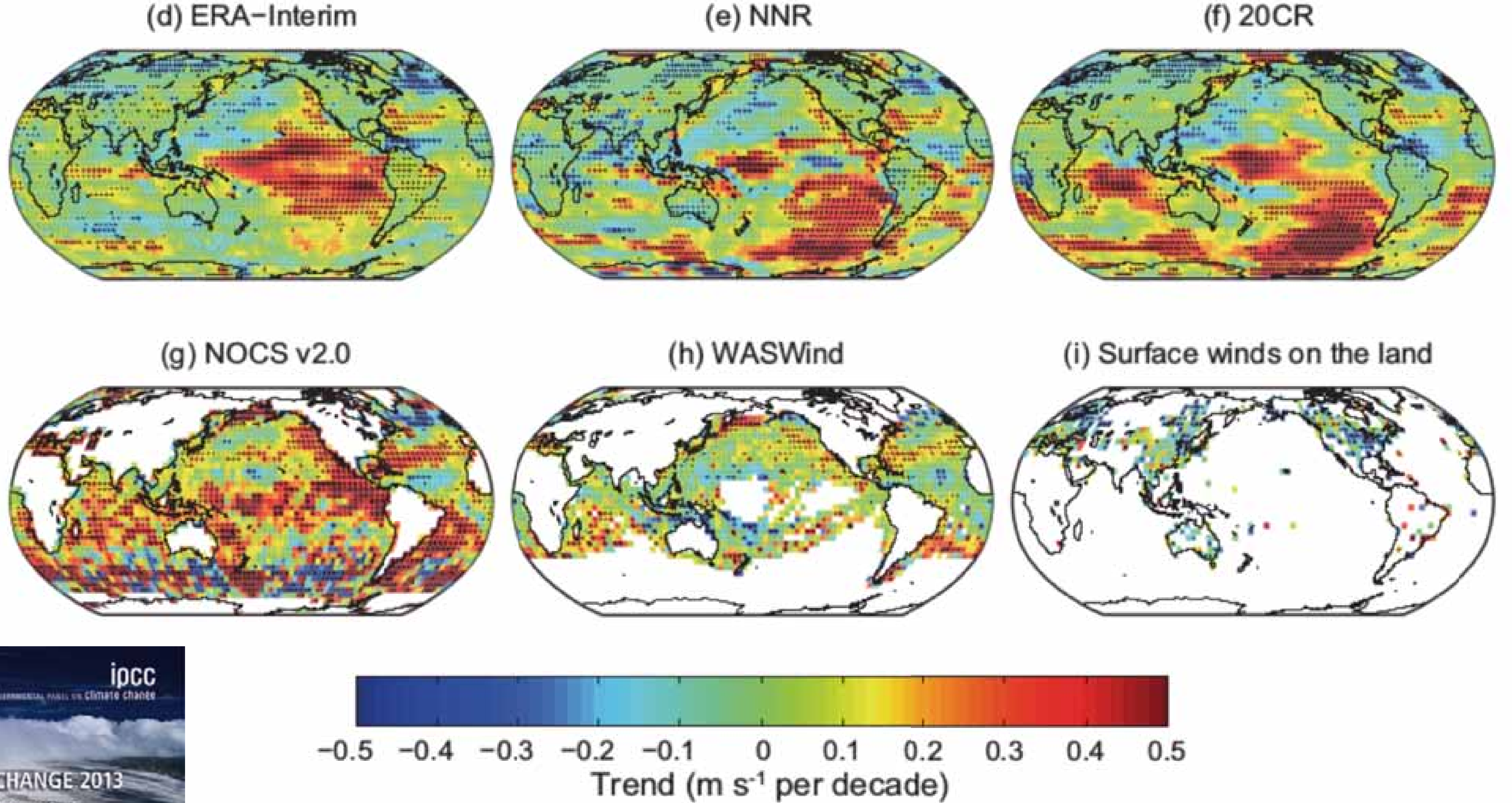
Changes in Climate Extremes and their Impacts on the Natural Physical Environment

Coordinating Lead Authors:
Sonia I. Seneviratne (Switzerland), Neville Nicholls (Australia)

Lead Authors:
David Easterling (USA), Clare M. Goodess (United Kingdom), Shinjiro Kanae (Japan), James Kossin (USA), Yali Luo (China), Jose Marengo (Brazil), Kathleen McInnes (Australia), Mohammad Rahimi (Iran) Markus Reichstein (Germany), Asgeir Sorteberg (Norway), Carolina Vera (Argentina), Xuebin Zhang (Canada)

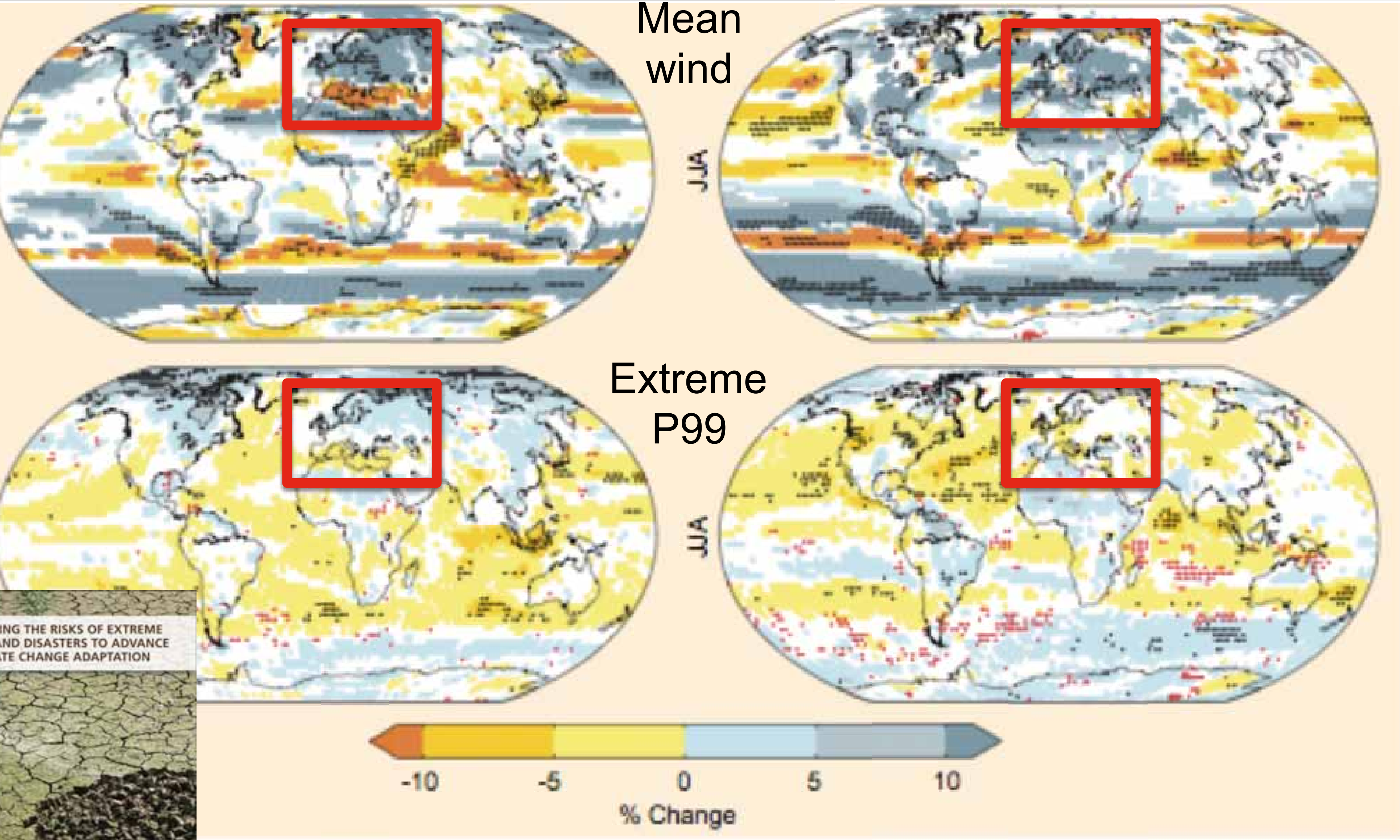
Review Editors:
Matilde Rusticucci (Argentina), Vladimir Semenov (Russia)

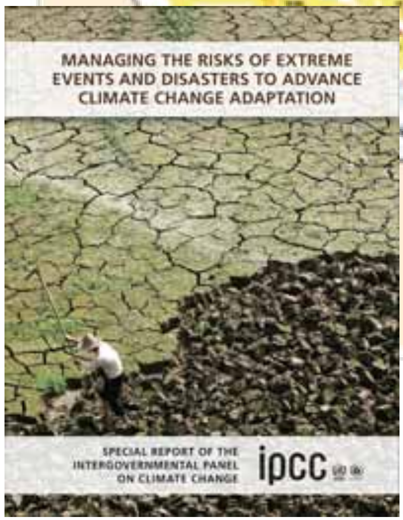
Past trends



In summary, *confidence* is *low* in changes in surface wind speed over the land and over the oceans owing to remaining uncertainties in data sets and measures used.

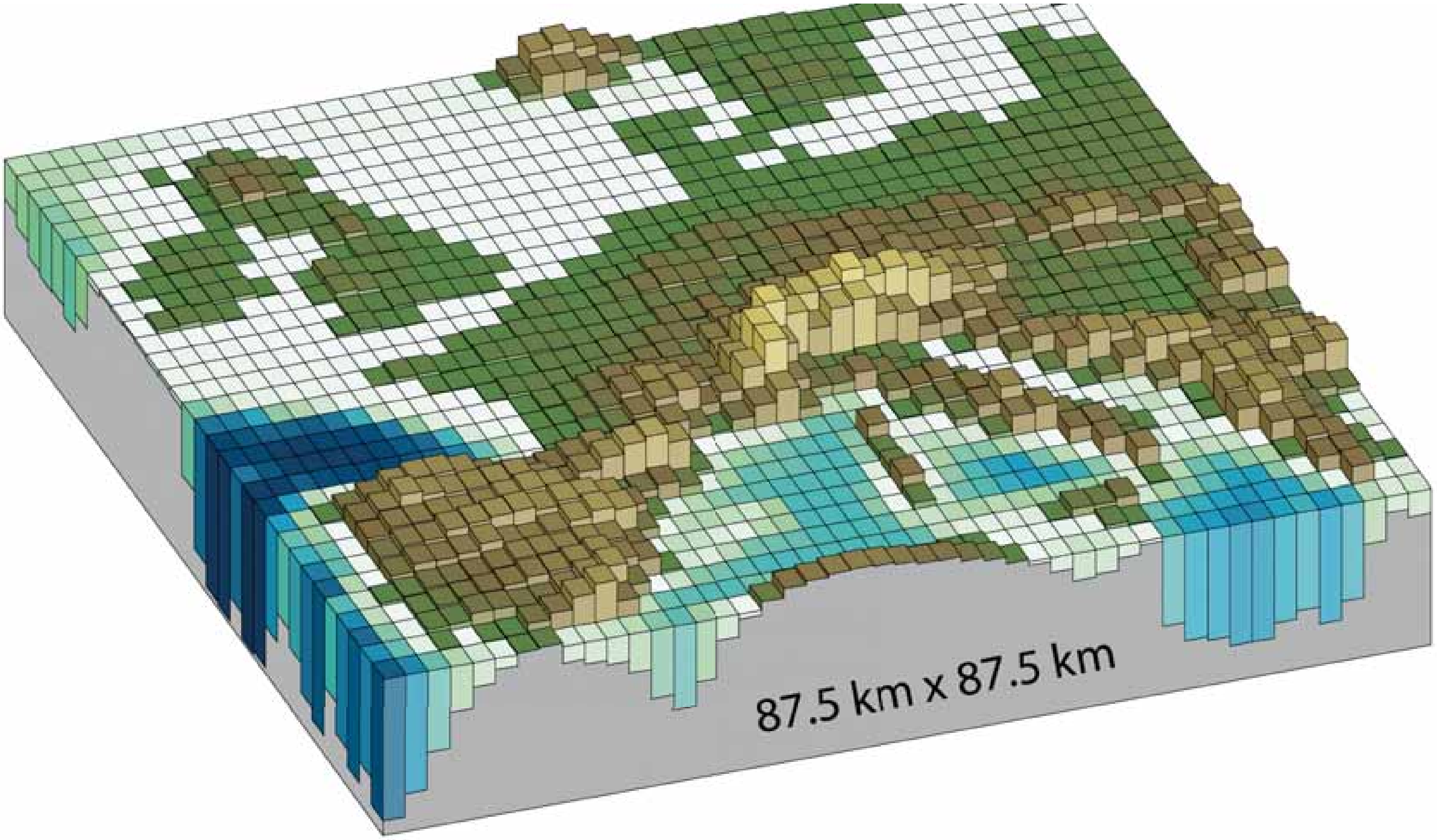
Future projections





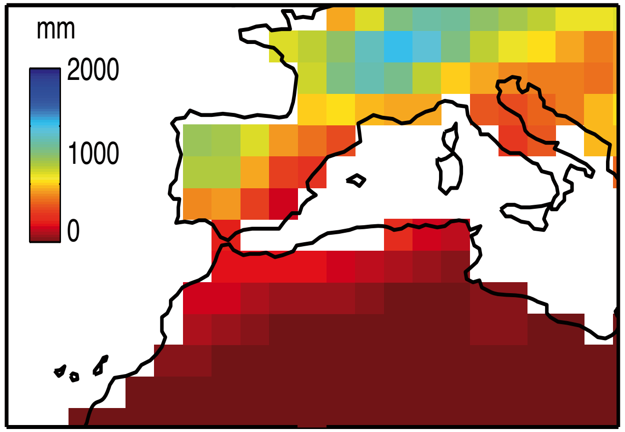
mean that **we have *low confidence* in projections of changes in extreme winds** (with the exception of changes associated with

GCM Limitations



The coarse resolution used to solve GCMs and the empirical representation of sub-grid processes (model parameterizations) severely **limit** the suitability of the GCMs to represent regional/local climate variability, particularly for surface variables (e.g. wind).

MODEL SPACE



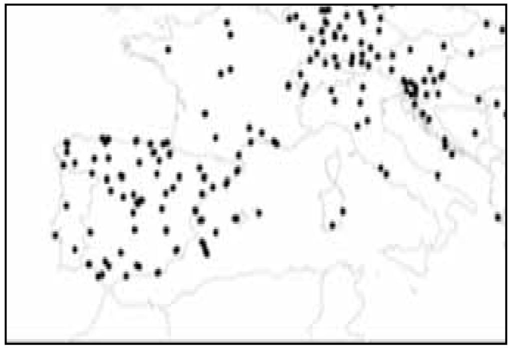
GCM outputs (**~200 km**)

Variables	Description	Units
tas	2-meter temperature	K
tasmax	Daily maximum 2-m temperature	K
tasmin	Daily minimum 2-m temperature	K
wss	10 m wind speed	m/s
wssmax	Daily maximum 10 m wind speed	m/s
hurs	2-meter relative humidity	%
tdps	2-meter dew point temperature	K
psl	Mean sea level pressure	Pa
pr	Precipitation	Mm
evspsbl	Evaporation	Mm
evspsblpot	Potential Evapotranspiration	Mm
rss	Net SW surface radiation	W/m^2
rls	Net LW surface radiation	W/m^2
rsds	Downward SW surface radiation	W/m^2
rlds	Downward LW surface radiation	W/m^2

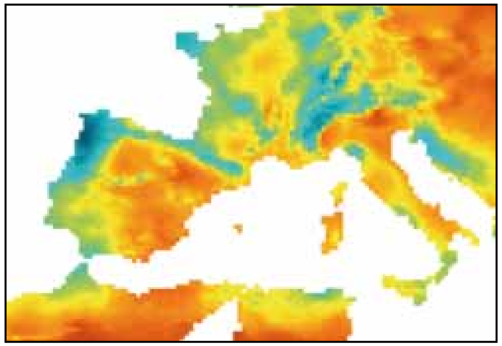
MODEL BIASES

RESOLUTION

REAL WORLD



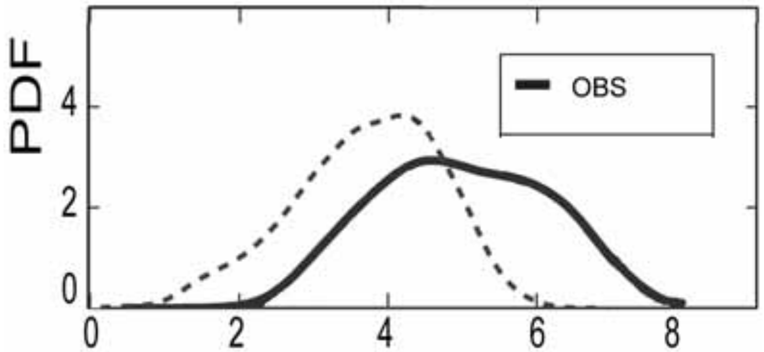
Local data (**points**)



Gridded data (**~10 km**)

[subdaily, daily temporal scale]

– Hydrology - Energy
– Agriculture - Insurance



Models exhibit biases when compared with observations:

1. Systematic model biases

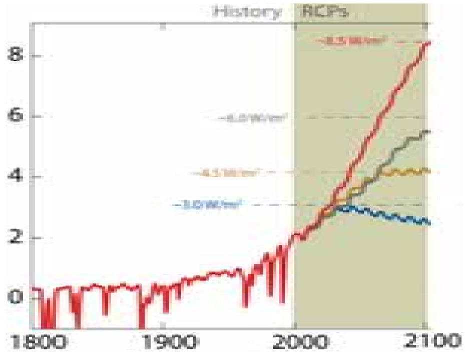
2. Different resolutions

Santander Meteorology Group

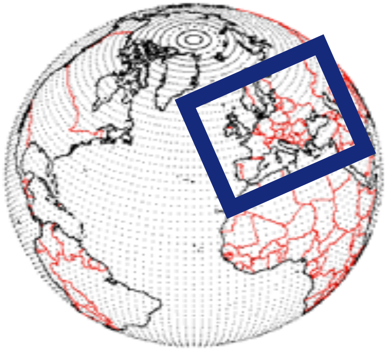
A multidisciplinary approach for weather & climate

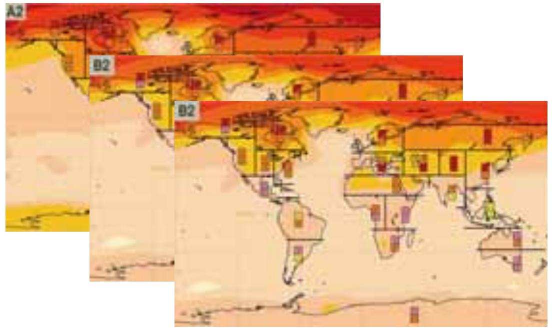
Statistical Downscaling (SDM)

Forcing



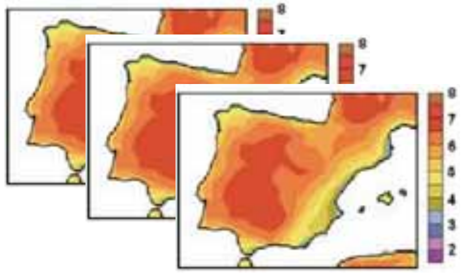
GCMs





Dynamical downscaling

Regional Climate Models (**RCMs**)

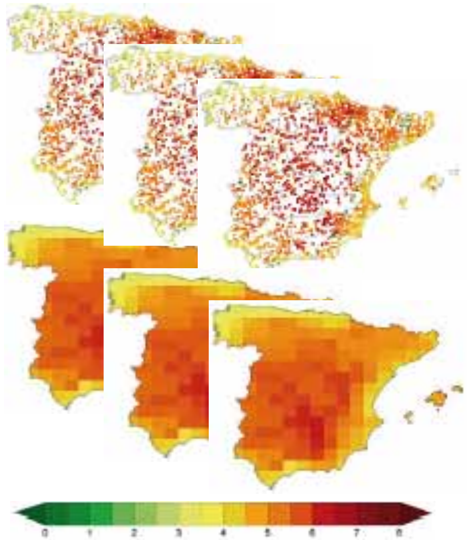


Bias correction

PP and MOS
Statistical downscaling

$$\mathbf{Y} = f\,(\mathbf{X};\theta)$$

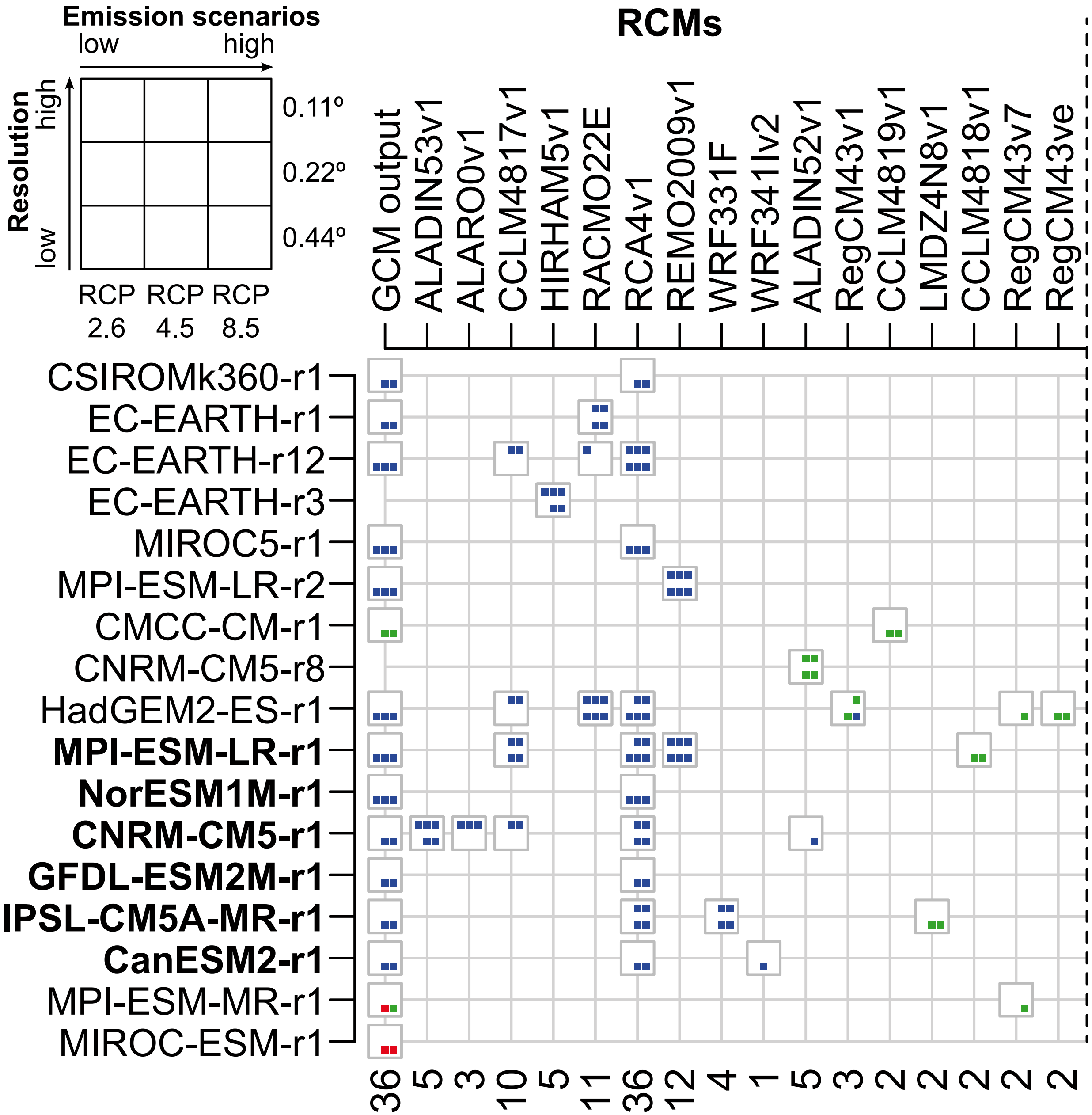
parameters are asjusted using historical data for both GCMs and observations.



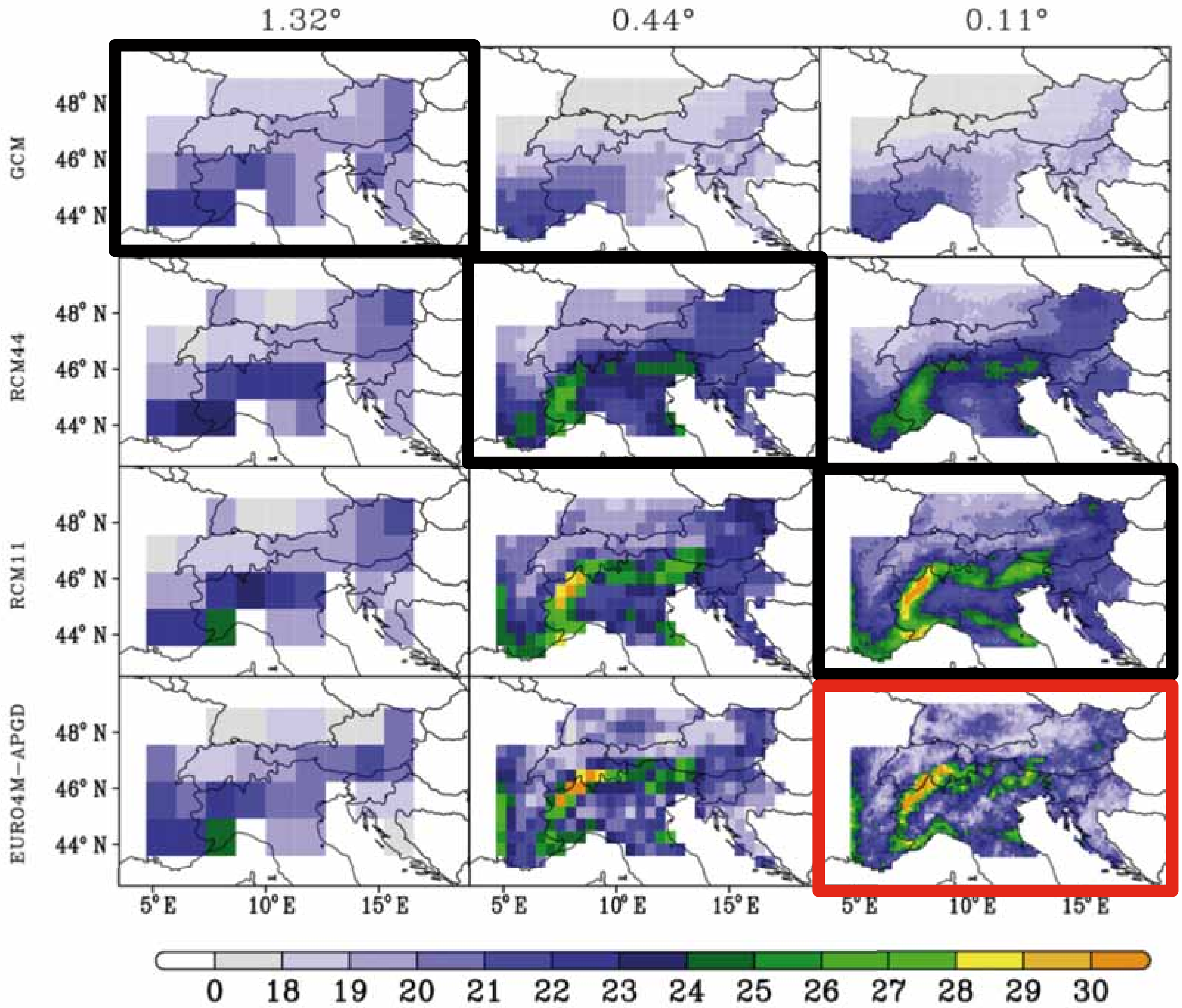
Regional Climate Models (RCMs)

Euro-CORDEX is the last of a series of international initiatives for regional climate change projection over Europe.

0.11º and **0.44º** resolution.



EURO-CORDEX


1.32°
0.44°
0.11°
GCM
RCM44
RCM11
EURO4M-APGD
48° N
46° N
44° N
5° E
10° E
15° E
0
18
19
20
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30

Storminess and wind

atmosphere MDPI

Review

Review on the Projections of Future Storminess over the North Atlantic European Region

Tina Mölter [1], Dirk Schindler [1,*], Axel Tim Albrecht [2] and Ulrich Kohnle [2]

Received: 16 February 2016; Accepted: 15 April 2016; Published: 22 April 2016

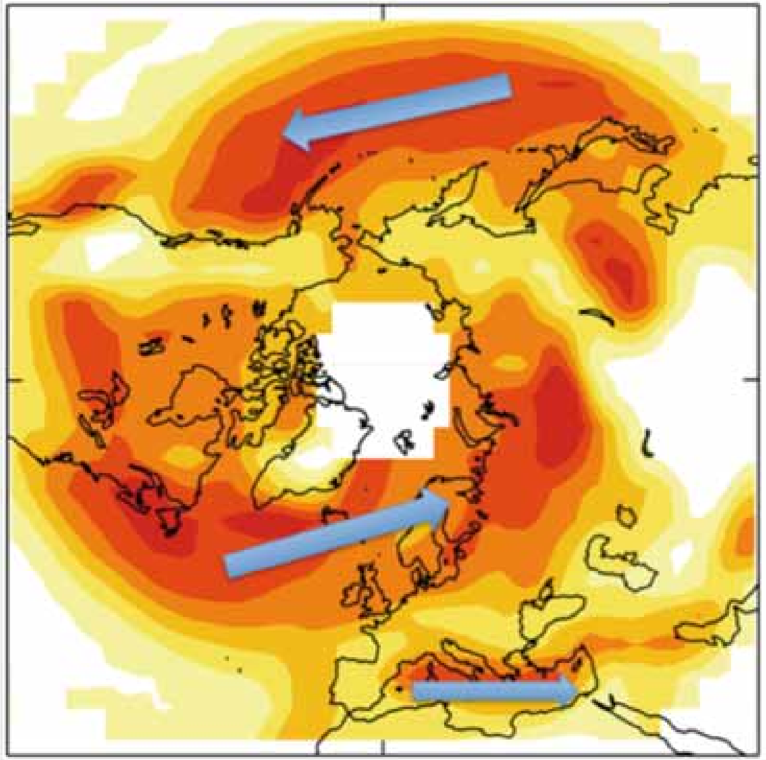
Extratropical **cyclones** can be defined as a minimum in the mean SLP field or at the 1000 hPa geopotential height ➔ "storm track"

Storm intensity can be characterized by wind speed at 10 m above the ground. In the reviewed literature, it was reported as:

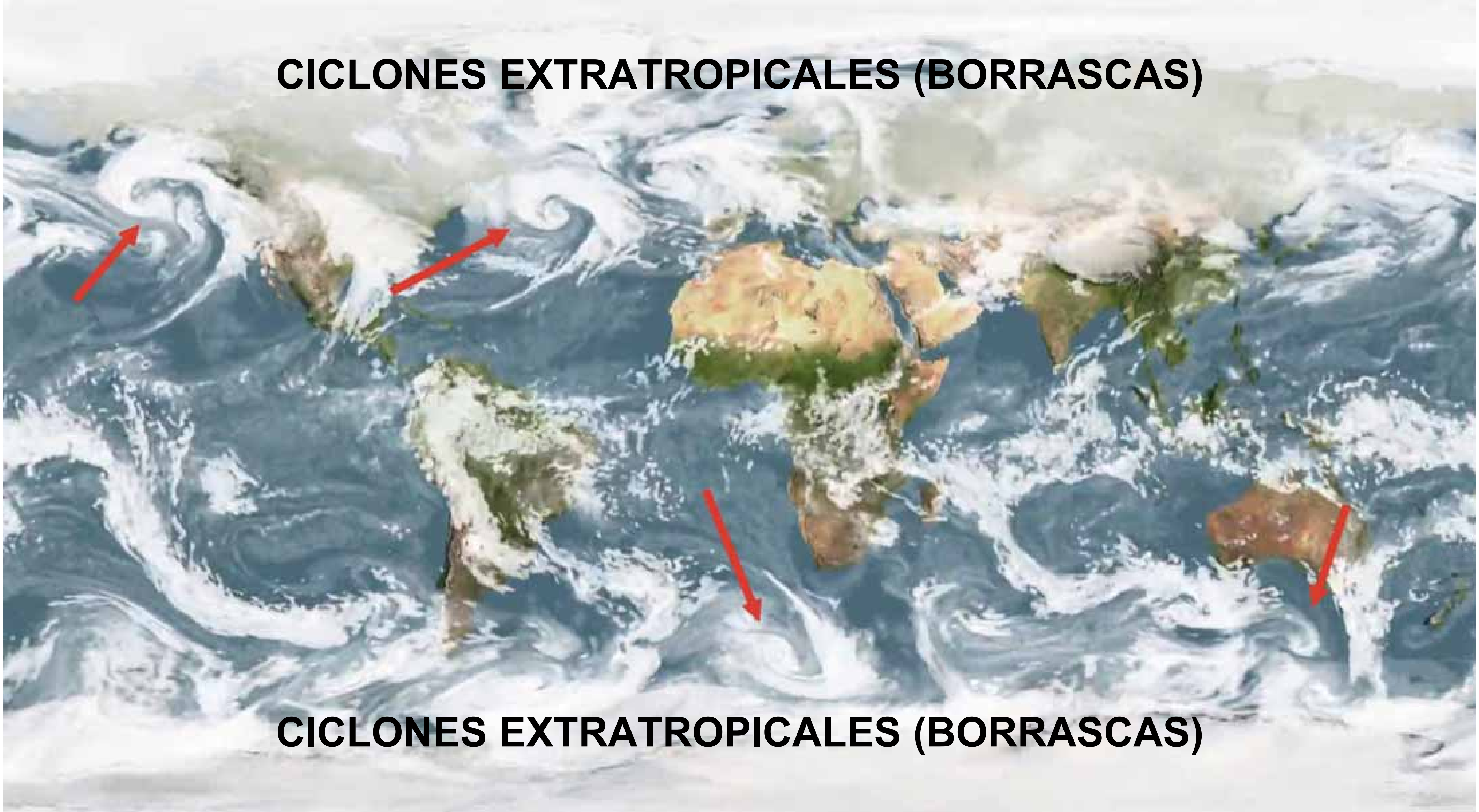
(i) peak 1-3 s wind gust speed;

(ii) mean 10 min wind speed; or

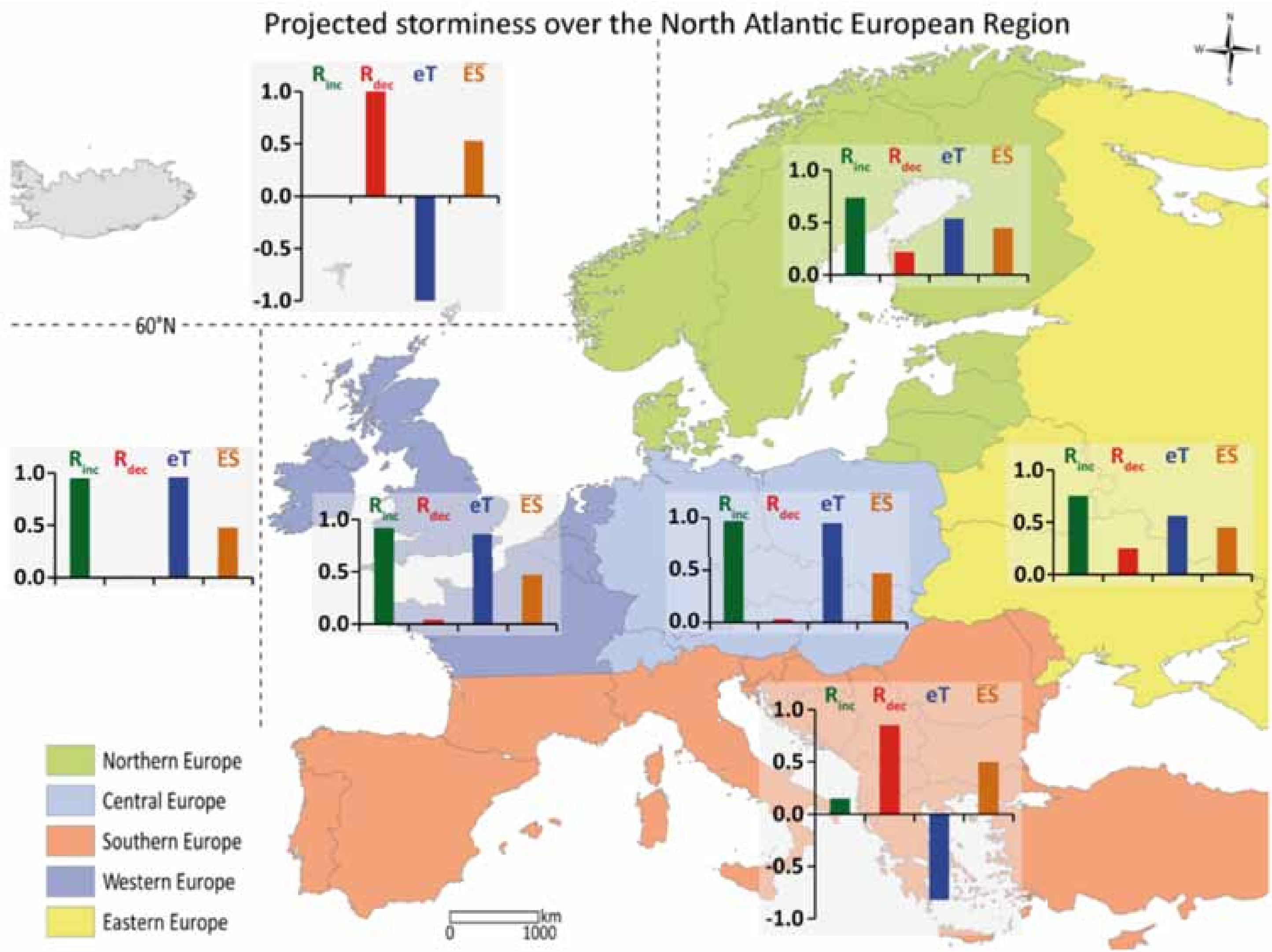
(iii) percentiles (e.g., 90–98 percentiles) of maximum daily wind speed values.



CICLONES: Borrascas ...



For Southern Europe (Mediterranean) "unambiguously suggests a decreasing tendency of the projected future extratropical storminess"



Most studies focused on Winter !!!

Study	Model(s)	Category	Reference Period(s), Projection Period(s), Month(s), Season	Region(s)
Zappa *et al.* (2013) [51]	GCM: 19 RCM: -	Cyclone intensity	1976–2005, 2070–2099, DJF	Mediterranean region
Gastineau and Soden (2009) [64]	GCM: 16 RCM: -	Wind intensity	1995–2000, 2095–2100, -	Southern Europe
Donat *et al.* (2011) [17]	GCM: 7 RCM: 9	Wind intensity	1960–2000, 2021–2050, 2071–2100, October–March	Mediterranean region
Nikulin *et al.* (2011) [66]	GCM: 6 RCM: 1	Wind intensity	1961–1990, 2071–2100, -	Europe south of 45°N
Schwierz *et al.* (2010) [27]	GCM: 2 RCM: 2	Wind intensity	1961–1990, 2071–2100, October–March	Mediterranean region
Bengtsson *et al.* (2006) [9]	GCM: 1 RCM: -	Cyclone intensity	1961–1990, 2071–2100, DJF	Mediterranean region (30°N–45°N 0°E–40°E)
Bengtsson *et al.* (2009) [31]	GCM: 1 RCM: -	Frequency of extreme cyclones, cyclone intensity	1959–1990, 2069–2100, DJF	Southern Europe (30°N–47.5°N, 10°W–40°E)
Beniston *et al.* (2007) [70]	GCM: 1 RCM: 7	Storm intensity	1961–1990, 2071–2100, DJF	Southern Europe (Alps and south of the Alps)
Fink *et al.* (2009) [38]	GCM: 1 RCM: 2	Storm frequency	1970–1999, 2070–2099, winter	Mediterranean region
Giorgi *et al.* (2004) [63]	GCM: 1 RCM: 1	Storm activity	1961–1990, 2071–2100, DJF	Southern Europe
Muskulus and Jacob (2005) [77]	GCM: 1 RCM: 1	Frequency of extreme cyclones	1961–2099, winter	Mediterranean region

Extreme events: *Explosive cyclogenesis*

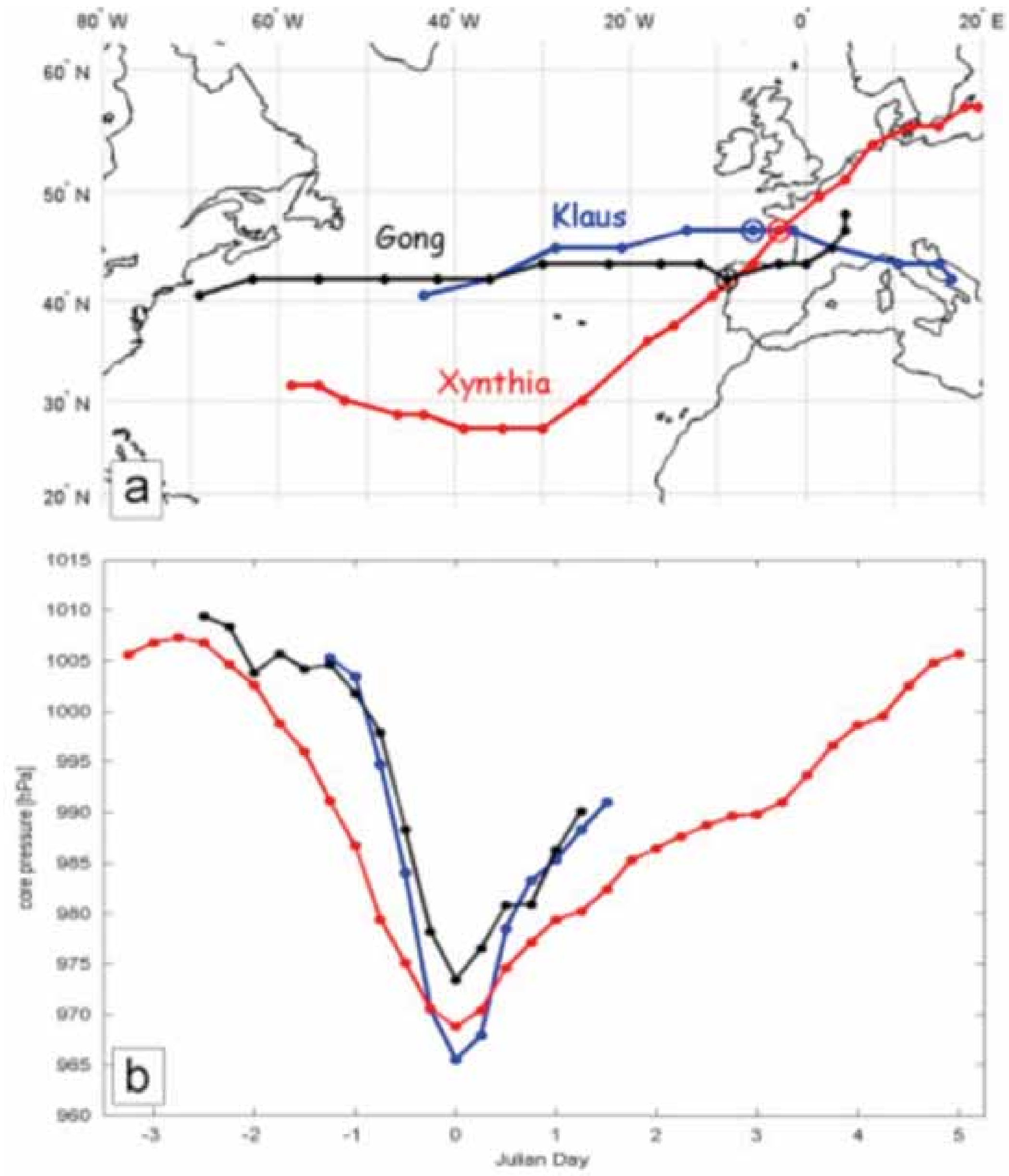


Fig. 2. (a) Cyclone tracks of recent extreme storms over the North Atlantic based on ECMWF ERA-Interim reanalysis data with dots indicating storms′ location at six hour intervals: Gong (January 2013, in black), Klaus (January 2009, in blue) and Xynthia (February 2010, in red). The open circle marks the location of the minimum core pressure for each storm. (b) Core pressure evolution over the lifetime of each cyclone (core pressure in hPa). Dates are relative to the minimum core pressure time (zero Julian day).

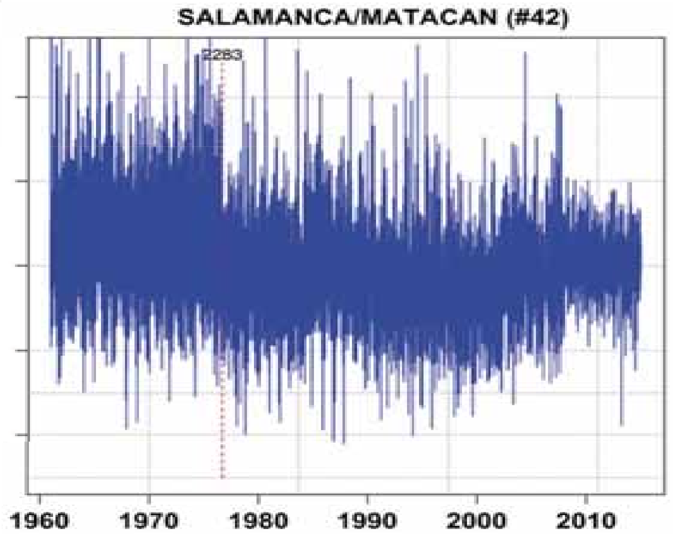
Observed trends in maximum wind

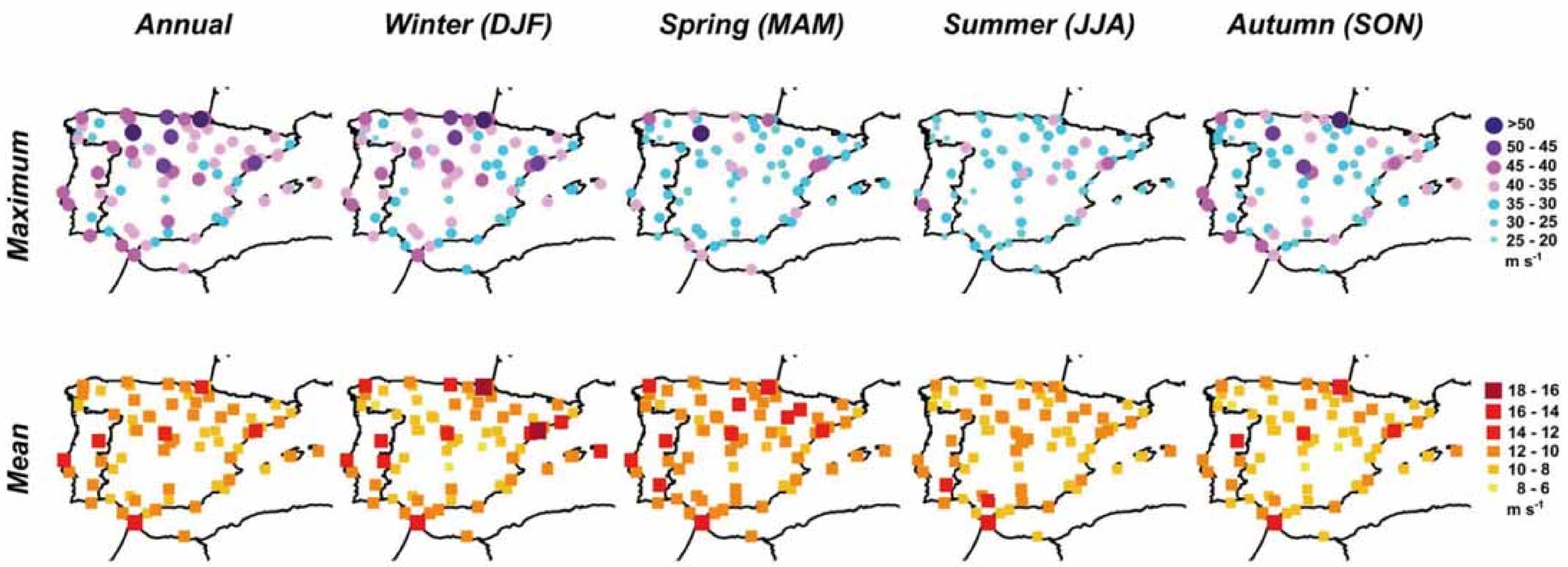
Trends of daily peak wind gusts in Spain and Portugal, 1961–2014

Cesar Azorin-Molina, Jose-A. Guijarro, Tim R. McVicar, Sergio M. Vicente-Serrano, Deliang Chen, Sonia Jerez, Fátima Espírito-Santo

First published: 5 February 2016 Full publication history

DOI: 10.1002/2015JD024485 View/save citation





Observed trends in maximum wind

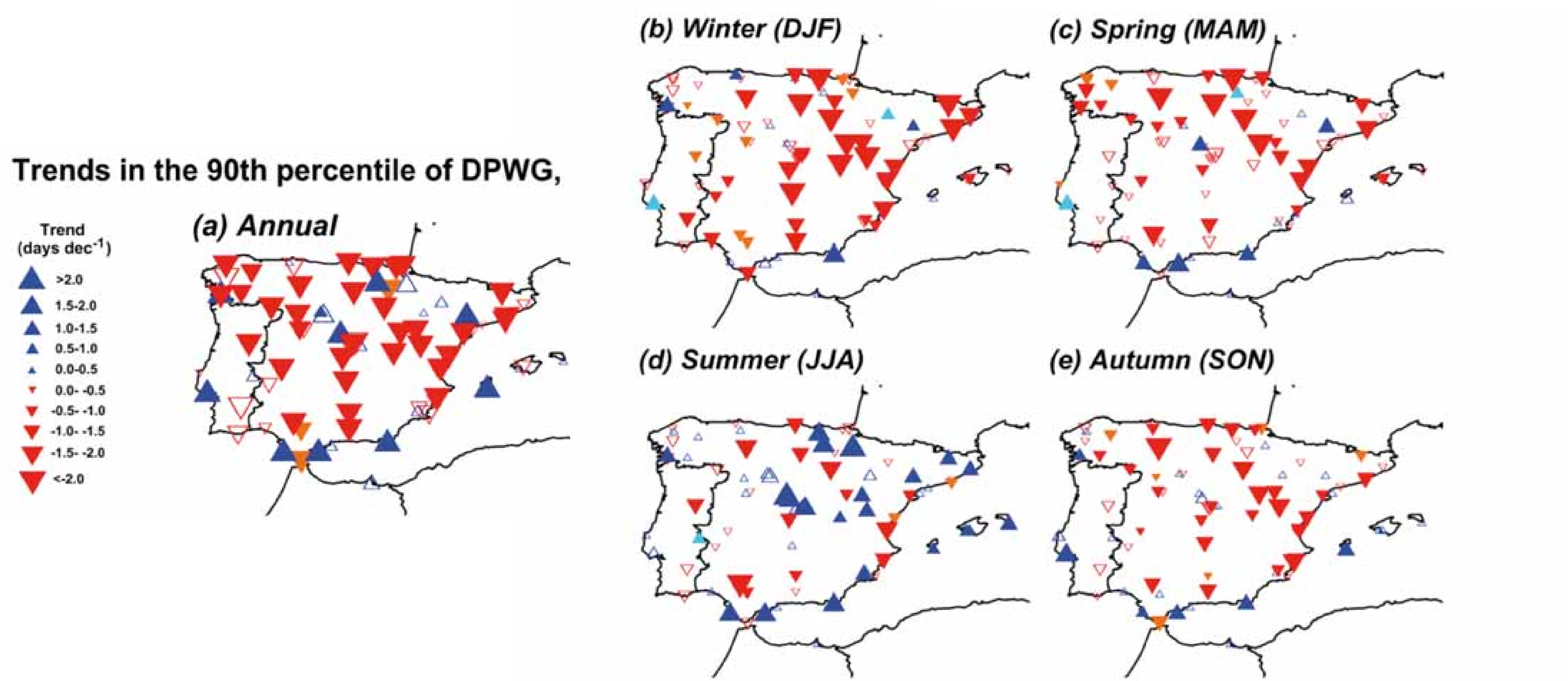


Figure 7. Spatial distribution of the sign, magnitude of trend (d decade^{-1}), and significance (blue and red filled triangles are significant at $p < 0.05$; light blue and orange filled triangles are significant at $p < 0.10$; and nonfilled triangles are not significant at $p < 0.10$) of annual and seasonal number of days exceeding the 54 year 90th DPWG percentile trends for 80 stations for 1961–2014.

Projected trends in maximum wind

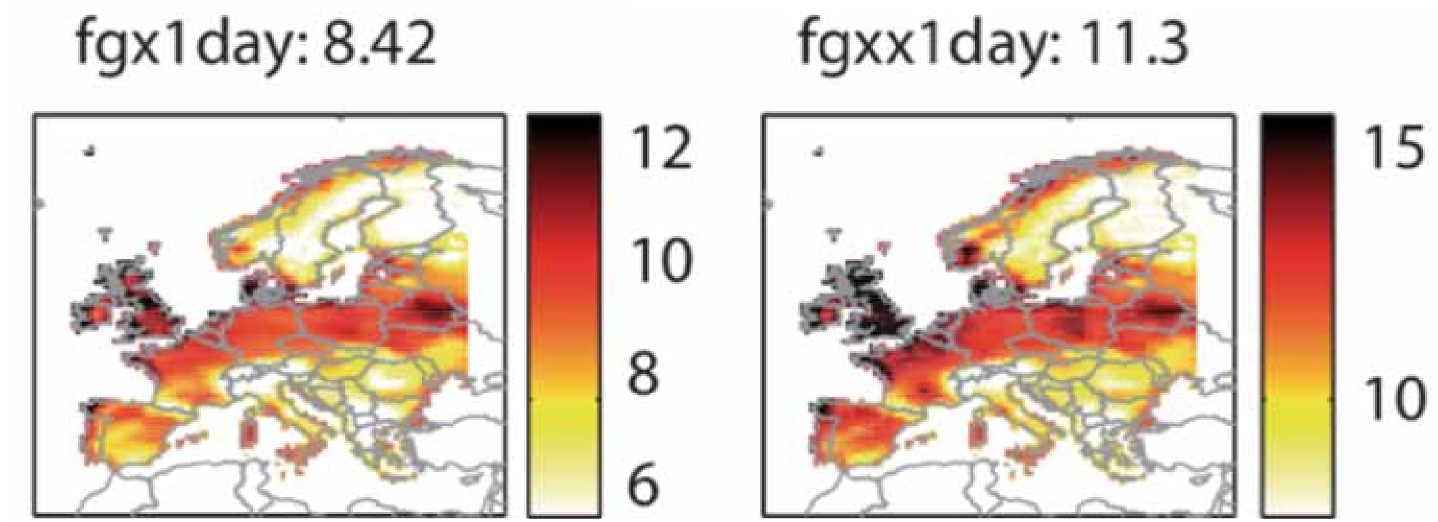
Impact of extreme weather on critical infrastructure

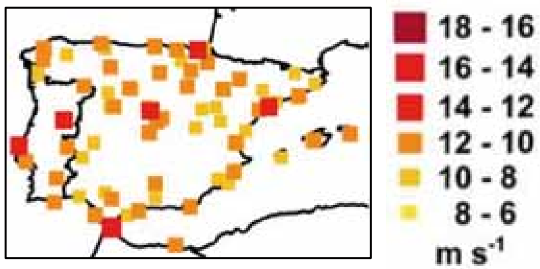
Table 2.2 Indicators based on wind, snow and humidity

Wind	Description	Units
FG	Average of daily mean wind speed	m/s
FGx1day	Yearly maximum of daily mean wind speed	m/s
FGXx1day	Yearly maximum of daily maximum wind speed of gusts	m/s
FG05	Number of days with wind speed > 5 m/s	days
FG10	Number of days with wind speed > 10 m/s	days
FG15	Number of days with wind speed > 15 m/s	days
FG25	Number of days with wind speed > 25 m/s	days
FGNN	Number of days with wind speed > NN m/s	days
Snow	**Description**	**Units**
SD1	Number of days with snow cover	days
SD010	Number of days with snow depth 0-10 mm	days
SD1020	Number of days with snow depth 10-20 mm	days
SDx1day	Yearly maximum snowfall	mm
SDratio	seasonal snowfall/ average total annual	1
Combined	**Description**	**Units**
HU90	Number of days when the relative humidity (daily mean) is above 90% and mean temperature > 10 ºC	days

Projected trends in maximum wind

Figure 4.1 Climatology of wind and snow indices for WFDEI data computed on yearly basis averaged over the time period 1981-2000





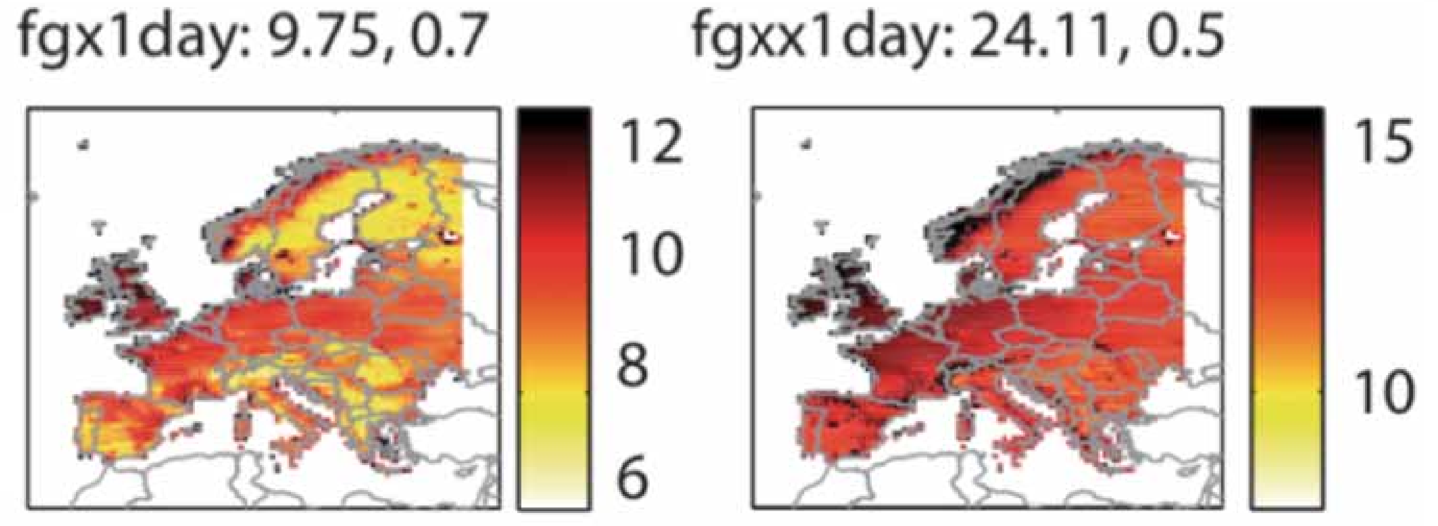
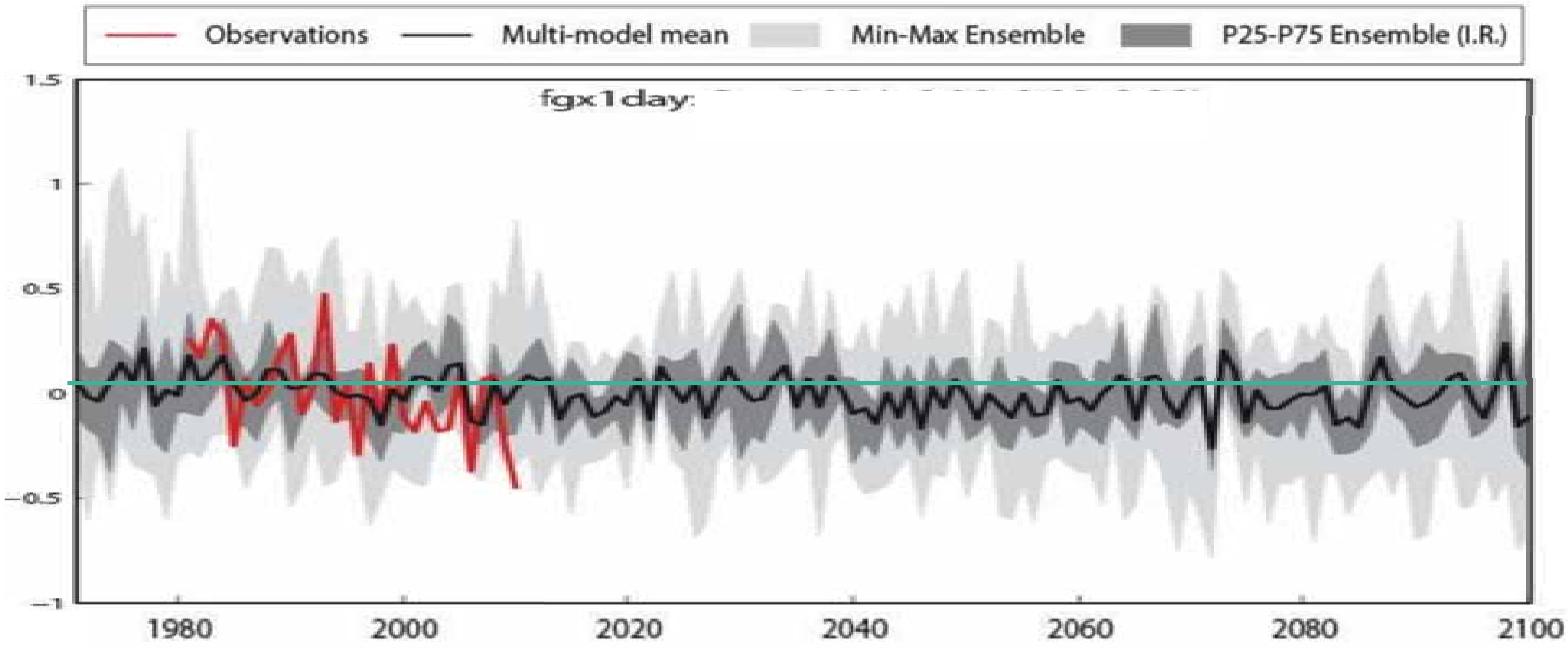
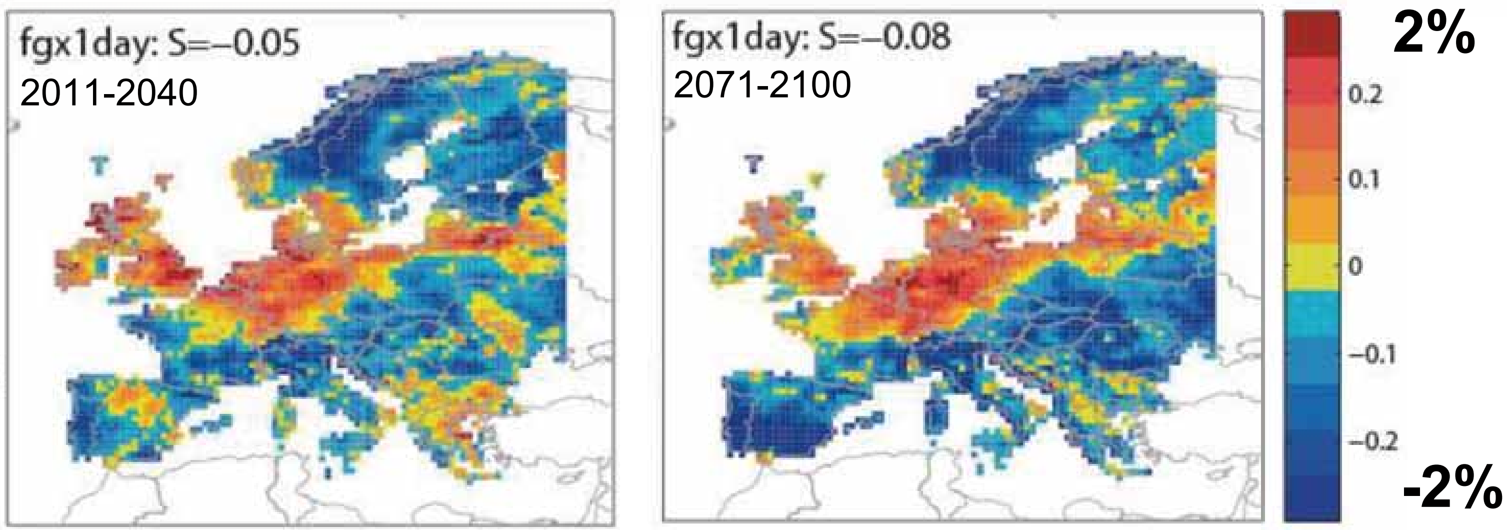


Figure 4.3 Climatology of wind and snow indices for ENSEMBLES data (multimodel mean), computed on yearly basis considering the time period 1981-2000

Projected trends in maximum wind





Storm-induced losses

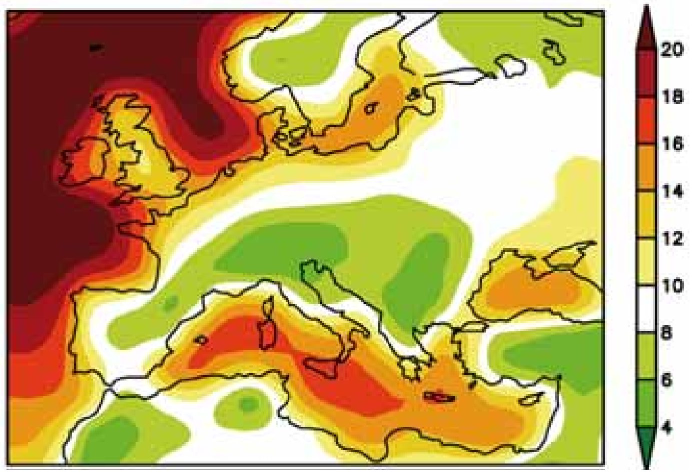
Future changes in European winter storm losses and extreme wind speeds inferred from GCM and RCM multi-model simulations

M. G. Donat[1,2], G. C. Leckebusch[1], S. Wild[1], and U. Ulbrich[1]

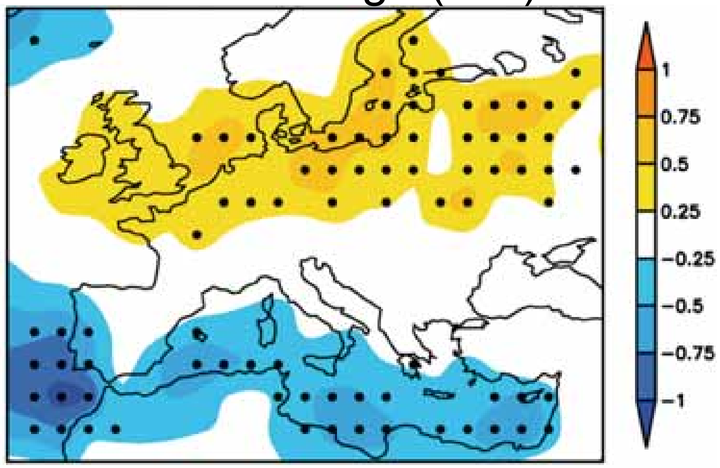
Nat. Hazards Earth Syst. Sci., 11, 1351–1370, 2011
www.nat-hazards-earth-syst-sci.net/11/1351/2011/
doi:10.5194/nhess-11-1351-2011

Results using ENSEMBLES data.

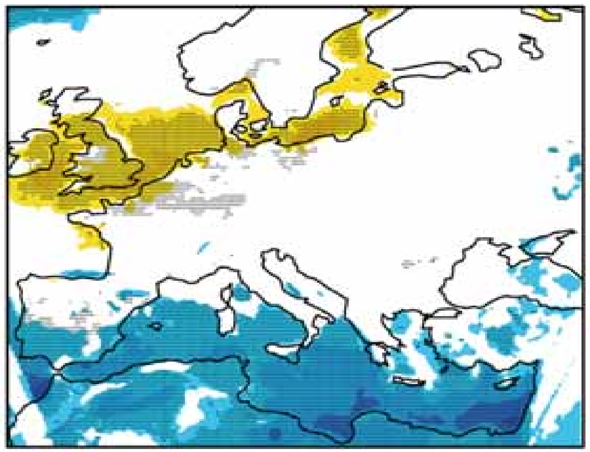
GCM P98 winmax



GCM Change (m/s)



RCM Change (m/s)



Wind power generation

LETTER · OPEN ACCESS

Climate change impacts on the power generation potential of a European mid-century wind farms scenario

To cite this article: Isabelle Tobin *et al* 2016 *Environ. Res. Lett.* **11** 034013

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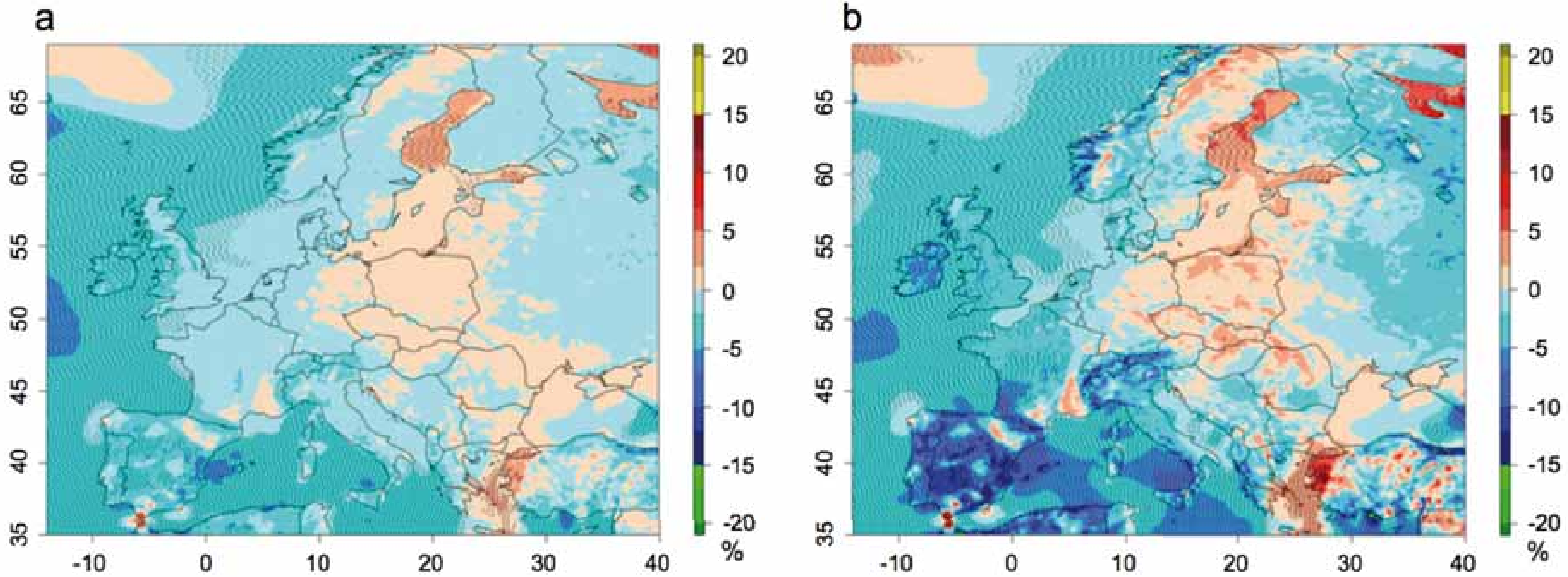


Figure 2. Ensemble mean future changes in wind speed at 10 m (a) and wind power generation potential (b) at the end of the century (2071–2100) relative to the recent 1971–2000 period under scenario RCP8.5. The black dots indicates where the changes are robust (95% significance over the model ensemble, according to Wilcoxon–Mann–Whitney test, and sign agreement over 80% of the models).

Storm-induced losses

The 21st century decline in damaging European windstorms

Laura C. Dawkins[1], David B. Stephenson[1], Julia F. Lockwood[2], and Paul E. Maisey[2]

Nat. Hazards Earth Syst. Sci., 16, 1999–2007, 2016
www.nat-hazards-earth-syst-sci.net/16/1999/2016/
doi:10.5194/nhess-16-1999-2016

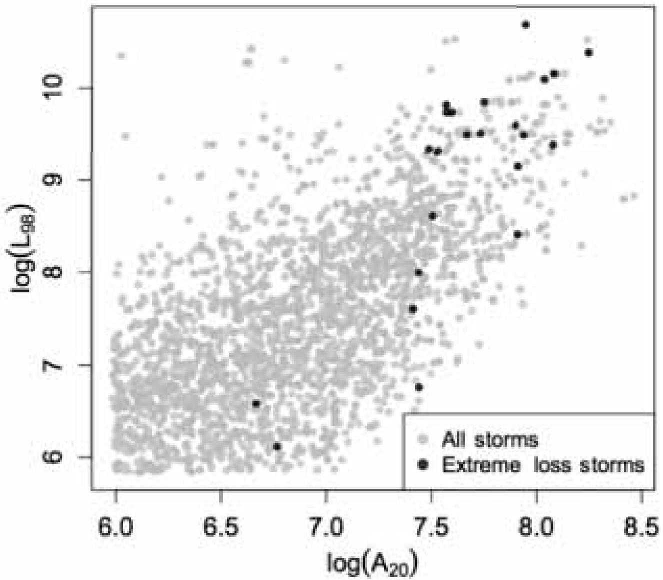
Klawa and Ulbrich (2003) developed an SSI for the estimation of windstorm losses in Germany. For windstorm event i, this SSI, here denoted L_{98}, was defined as

$$L_{98i} = \sum_{i=1}^{J} d(s_j)\left(\frac{v_i(s_j)}{v_{98}(s_j)} - 1\right)^3$$

for $v_i(s_j) > v_{98}(s_j)$,

Roberts et al. (2014)

$$A_{20i} = \sum_{j=1}^{J} H(v_i(s_j) - 20),$$



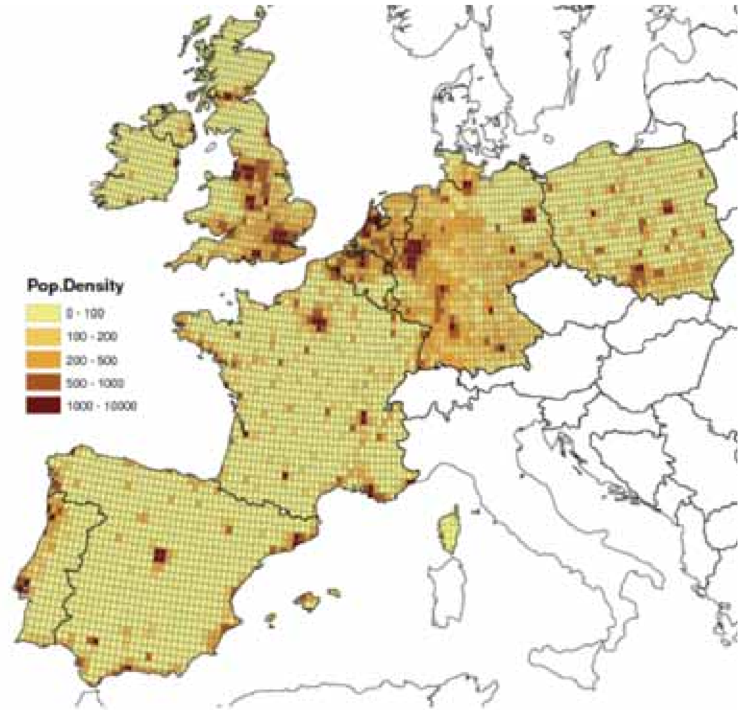


Fig. 1. Population density on a 0.25° × 0.25° grid (source: CIESI

Met Office unified model

The 21st century decline in damaging European windstorms

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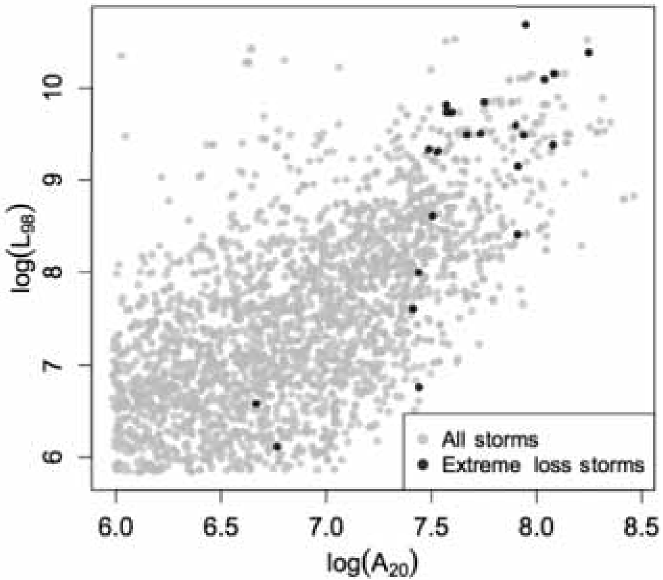
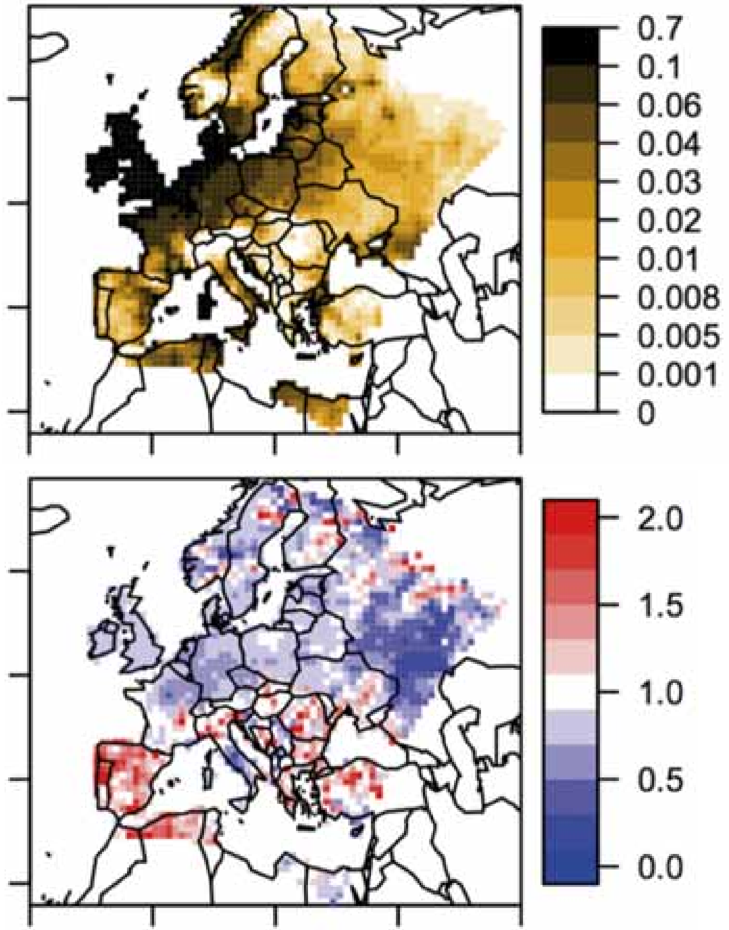


Met Office unified model

Relative freq. of exceeding 20 m/s in the 20th century and ratio of the relative frequencies in the 21st and 20th centuries.



Conclusiones

A diferencia de otras variables (temperatura o precipitación), las proyecciones de cambio climático de viento tienen poca señal a escala global.

A escala regional (Iberia), no se han estudiado suficientemente las proyecciones de viento extremo, así como el potencial de daño derivados, a través de índices y cambios en los patrones físicos..

PNACC Plan Nacional de Adaptación al Cambio Climático

ESCENARIOS-PNAC 2017

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Proyecciones Regionales de Cambio Climático Para Vientos Extremos en España Para el Siglo XXI

Julio 2017 - Junio 2018

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MINISTERIO DE AGRICULTURA, ALIMENTACIÓN Y MEDIO AMBIENTE

Gracias

Tracks of the 200 most intense winter cyclone tracks (1989-2009) in the north Atlantic (white lines).