Cambios futuros para V10 y la densidad de energía eólica marina utilizando proyecciones del CMIP6 en el océano Atlántico Norte

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Comisión: *Variabilidad y cambio climáticos (I)*

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Introduction

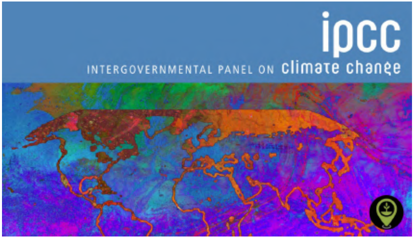


Figure: **IPCC, 2021**.

- Precipitation and Temperature (and its extremes).
- Sea level rise and Arctic sea ice.
- Atmospheric circulation changes.

Ramanathan and Feng (2008), Xu and Ramanathan (2017), Steffen et al. (2018)

Variables needing more detailed analysis

- Wind speed (which is important for renewable energies).

According to the sixth report of the IPCC

Processes or mechanisms that need to be improved on a regional scale **(IPCC, 2021)**.

Wind field and offshore energy

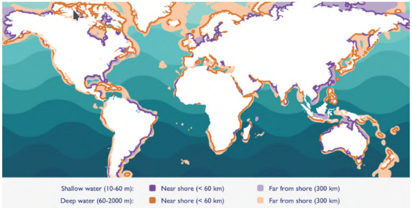


Figure: Global map of offshore wind potential. Source: IEA OffShore Wind Outlook 2019.

- North Atlantic (Europe and the United States East Coast).

- Wind speed at a height of 10 m (V10) strengthening can aggravate moisture and heat fluxes at the air-sea interface or increase soil erosion.
- The changes in V10 influence evaporation.
- Decreases in V10 led to a decrease in the expansion of drought areas in China.
- A 1–5% decrease in wind speed can lead to 1.7–8.6% losses in wind energy generation.
- Global climate models (GCMs) have been used to analyse future wind changes and their implications for wind energy.

Stocker et al. (2013), Liu et al. (2014)

The low resolution of the GCM does not show detailed signals of climate change and its effects in a specific region.

General Objective: Evaluate future changes for wind and offshore wind energy in the North Atlantic region.

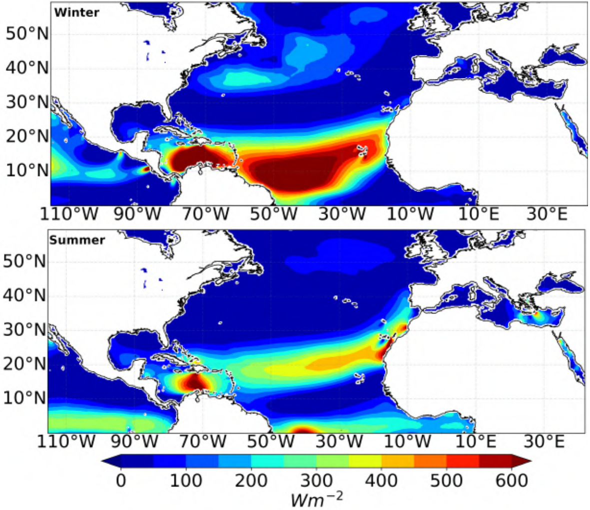


Figure: Wind power density maps to ERA5 data.

Domains for the WRF-ARW and FLEXPART-WRF models and the parametrisation schemes

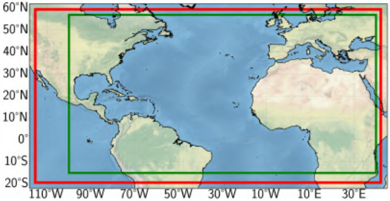


Figure: Domains used for the WRF-ARW (red) and FLEXPART-WRF (green) models.

WRF-ARW configuration details

- WRF-ARW (~ 0.18°, 480x800).
- Spectral nudging of waves longer than 1000 km.
- The parametrisations have been evaluated for the region (e.g., **Insua-Costa and Miguez-Macho 2018; Insua-Costa et al. 2019**).

Table: WRF-ARW

Scheme type	Name
Longwave scheme	RRTMG
Shortwave scheme	RRTMG
Cumulus scheme	Kain-Fritsch
Microphysics scheme	WSM6
Planetary boundary-layer	Yonsei University
Surface layer	Revised MM5
Land model	Noah Model

Offshore wind power density (WPD) determination

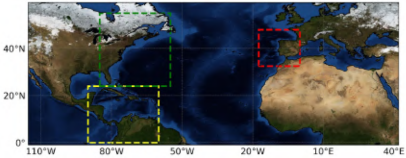


Figure: Areas considered for the analysis of wind speed at 10 m (full area) and the WPD in the North Atlantic Ocean.

- The Atlantic coast of the IP (red box).
- The East coast of the United States (US, green box).
- The Caribbean Sea region (CS, yellow box).

$$WPD = \frac{1}{2}\rho v^3$$

$$v = u_{zm} \cdot \left(\frac{ln\,\frac{h}{z_0}}{ln\,\frac{hm}{z_0}} \right)$$

- u_{zm} is V10 (m/s)
- $h_m = 10$ m and $h = 120$ m are the height for the wind speed
- v (m/s) is the wind speed extrapolated to 120 m
- $z_0 = 1.52 \cdot 10^{-4}$ is the local roughness length
- $\rho = 1.225\ \mathrm{kg/m^3}$ is air density

Swart et al. (2009), Ulazia et al. (2019)

V10 obtained from the WRF-ARW outputs is evaluated with respect to ERA5 data.

Results and Discussion

Evaluate future changes for wind and offshore wind energy in the North Atlantic region (**Energy Reports, 2023**).

- **Data**
  - ERA5 reanalysis
  - CESM2 model output (SSPs: 4.5, 7.0 and 8.5)
- **Method**
  - WRF-ARW
- **Periods**
  - HIST_5Y: 2010-2014
  - MC_5Y: 2049-2053
  - EC_5Y: 2096-2100
- **Regions**
  - North Atlantic ocean (NATL, V10)
  - Iberian Peninsula atlantic coast (IP, WPD)
  - United States atlantic coast (US, WPD)
  - Caribbean Sea (CS, WPD)

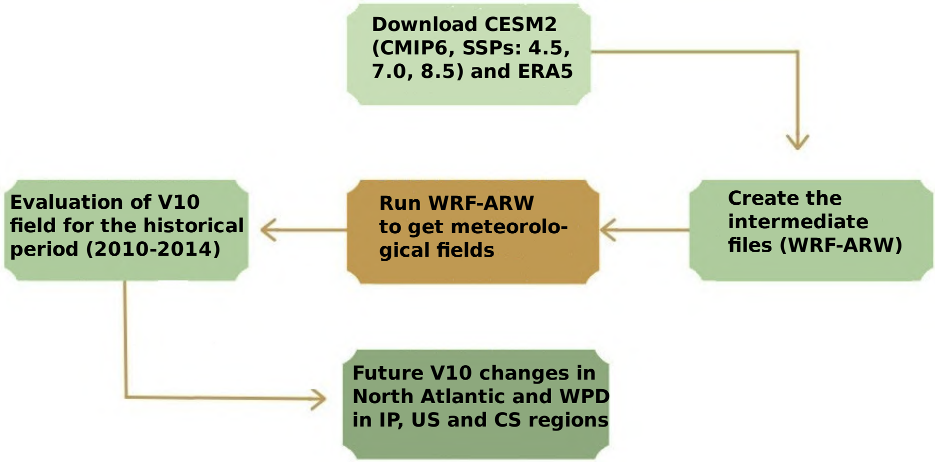
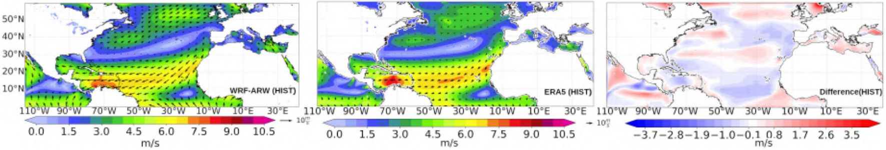
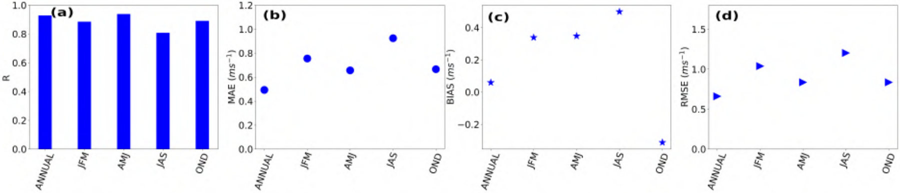


Figure: Flowchart implemented.

Evaluation of the downscaling methodology for V10

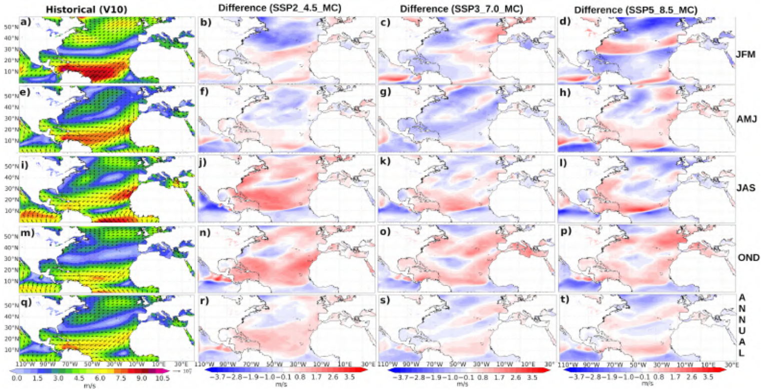


- Annually, simulated data show very similar behaviour with spatial differences of $\leq 0.8\ \mathrm{m\ s^{-1}}$ across the NATL.



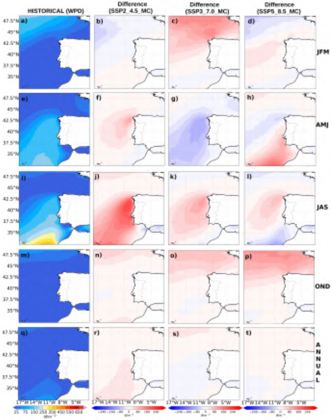
- $\mathrm{R} \geq 0.8$
- MAE from $0.5 - 1.0\ \mathrm{m\ s^{-1}}$ (higher in summer and lower in autumn).
- Overestimates (Bias) in all periods (except autumn).
- RSME from $0.8 - 1.2\ \mathrm{m\ s^{-1}}$ and ~ 0.6 (annually).

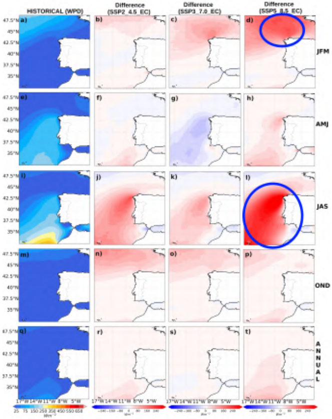
Future changes for V10 North Atlantic Ocean determined using WRF-ARW and SSPs



- Under SSP2-4.5 and SSP3-7.0 (MC), a decrease (increase) is projected for winter and spring (summer and autumn). Small differences for IP and West Africa.
- Under SSP5-8.5 (MC), marked decreases observed over the Caribbean Sea and African coast and at latitudes over 50°N (in winter).
- Increasing trend in North Atlantic Ocean region for summer and autumn (SSP5-8.5, EC).

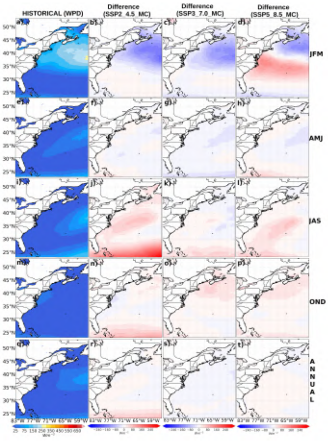
Future changes for WPD in the Iberian Peninsula subregion

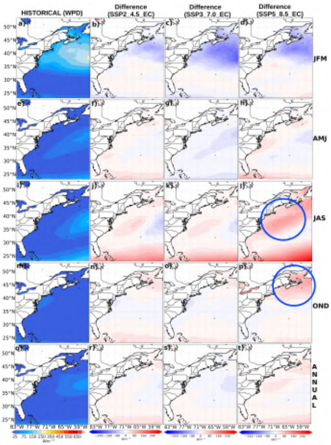




- Considerable increase is expected for autumn and summer for both study periods.
- In winter for MC there are discrepancies between the SSPs but for EC project a notable increase (mainly for SSP5-8.5).

Future changes for WPD in the US subregion

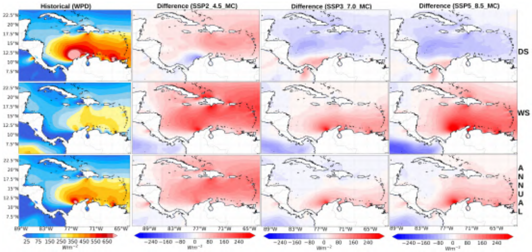




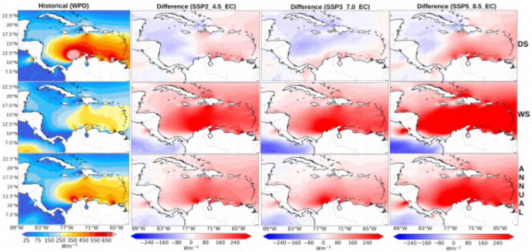
- Decrease in WPD in winter considering all SSPs and an increase in summer.
- Little change over the remaining periods, except in autumn.

Future changes for WPD in the Caribbean Sea subregion

Period: Dry season (DS), Wet season (WS) and Annual.



- SSP2-4.5 projects an increase in all periods.
- In DS the SSP3-7.0 and SSP5-8.5 project a decrease mainly on the coast of Colombia.
- In WS and annually, the SSP3-7.0 and SSP5-8.5 show an increase near the coast of Colombia and Venezuela.



- Decrease (increase) in the WPD values in the Yucatan and Colombia (Venezuela) basins was projected for all SSPs in the dry season.
- Notable increase in WPD values was projected in the Caribbean Sea for wet season and annually (exception: the Yucatan Basin).

Dynamic downscaling of wind speed over the North Atlantic Ocean using CMIP6 projections: Implications for offshore wind power density

These results were published in the Energy Reports journal in 2023.

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Research paper

Dynamic downscaling of wind speed over the North Atlantic Ocean using CMIP6 projections: Implications for offshore wind power density

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Conclusions

- V10 is projected to increase in tropical regions up to 30 °N in the summer and autumn seasons; however, it will decrease in winter and spring.
- Throughout the 21st century, a notable increase in wind energy density is projected in summer over the Atlantic coast of the Iberian Peninsula. A different behaviour is projected over the east coast of the United States, with decreases in winter but increases in summer and autumn. In the Caribbean Sea, marked increases are expected over the Colombia and Venezuela Basins but decreases in the Yucatan Basin.

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