Supporting Information for
“Current and Future Estimates of Wind Energy Potential over Saudi Arabia”

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Text S1. Return level

The $M$-year return level of wind speeds is defined as an extreme event that occurs on average once every $M$ years. Following the standard univariate extreme value theory [Davison and Smith, 1990], we can model the wind speed variable $Y$ over a high threshold $u$ by the Generalized Pareto Distribution $GPD(\tau, \xi)$:

\[
Y - u | Y > u \sim H(y) = \begin{cases} 
1 - (1 + \xi \frac{y}{\tau})^{-1/\xi}, & \xi \neq 0, \\
1 - \exp(-\frac{y}{\xi}), & \xi = 0,
\end{cases} \tag{S1}
\]

where $(x)_+ = \max(x, 0)$, and $\xi$ and $\tau > 0$ are shape and scale parameters, respectively. Hence, the distribution of $Y$ is given by

\[
P(Y \leq y) = G(y) = \begin{cases} 
1 - \zeta_u \left(1 + \xi \frac{y-u}{\tau}\right)^{-1/\xi}, & \xi \neq 0, \\
1 - \zeta_u \exp(-\frac{y-u}{\xi}), & \xi = 0,
\end{cases} \tag{S2}
\]

where $\zeta_u = \Pr(Y > u)$ is the probability of exceedance. The $M$-year return level $z_{1/M}$ (with return period $M$) of $Y$ is simply

\[
z_{1/M} = G^{-1}(1 - 1/M). \tag{S3}
\]

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For dependent data (which is the case in our study where the temporal dependence of wind speeds in summer is found to be strong in some locations), one has

\[ P(Y \leq y) \approx \{G(y)\}^{n_{\text{year}}\theta}, \quad y > u, \tag{S4} \]

where \( \theta \) is the extremal index that measures the degree of dependence in the data, and \( n_{\text{year}} \) is the number of observations per year. Hence, the \( M \)-year return level of wind speed is given by

\[
1 - \frac{1}{M} = \left\{1 - \zeta u \left(1 + \xi \frac{z_{1/M} - u}{\tau}\right)^{-1/\xi}\right\}^{n_{\text{year}}\theta} \approx \frac{1 - \zeta u \left(1 + \xi \frac{z_{1/M} - u}{\tau}\right)^{-1/\xi}}{\xi} \quad \text{for } \xi \neq 0.
\]

\[ \Rightarrow \frac{z_{1/M}}{M} \approx \frac{1 - \zeta u}{\xi} \left\{(n_{\text{year}} M \theta \zeta u)^{\xi} - 1\right\}. \tag{S6} \]

**References**


**Figure S1.** Spatially averaged daily mean wind speed during 1980-2005 for MERRA, MERRA-2, ERA-Interim and the five CORDEX runs.
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