Assignment 4 (Simple <u>Wind Resource and Site Assessment</u>).

The assignment is divided in two parts: wind resource assessment, and site assessment; each covers important aspects of the course material. First, we estimate the Annual Energy Production (AEP) at two hypothetical/potential turbine sites; hereafter the extreme winds are estimated for these sites.

We consider two locations for our assessment (wind turbine siting):

A) in the western Great Belt, close to Nyborg;

B) in the eastern Great Belt, close to Korsør.

These are basically on either side of the Great Belt bridge[1], where the island 'Sprog' (Sprogø) is in the middle between the two. Look on a map to check the relevant geography (one may also inspect e.g. the Danish Wind Atlas).

In this exercise, you may assume constant roughness lengths of $z_0 = 0.02$ cm over water and $z_0 = 3$ cm over land. For the wind turbine hub heights here, use $z_{\mathrm{hub}} = 110$ m.

The AEP in one sector is

$$E_i = T f_i \int_0^\infty p_i(U) P(U) \mathrm{d}U \tag{5}$$

where T is the length of one year (typically expressed in hours), f_i is the frequency of occurrence of wind directions in sector i, and $p_i(U)$ is the pdf of wind in the ith sector. The power curve $P(U)$ is given by the simple expression

$$P(U) = (6\mathrm{MW}) \times \begin{cases} (U/U_{\mathrm{rp}})^3 & \text{for } U < 12.5 \text{ m/s} \\ 1 & \text{for } 12.5 < U < 25 \text{ m/s} \\ 0 & \text{for } U > 25 \text{ m/s} \end{cases} \tag{6}$$

where $U_{\mathrm{rp}} = 12.5$ m/s is the rated power.

1. Calculate the AEP in units of MWh for a turbine having the power curve given by eqn. (6), at each of the two sites; do this using the data from Sprogø (file `sprogo_1.zip` from Assignment 1). You may use the Weibull-A and k parameters from the distributions obtained in Assignment 1, and assume that k does not change when going from Sprogø to the two sites.

   (a) You are, in effect, 'vertically extrapolating' from $z = 70$m to $z_{\mathrm{hub}} = 110$ m. If the Weibull-k parameter actually decreases by 10% over this vertical extent, then are you justified in ignoring its variation? (Support this with numbers!)

   (b) Now find the least-windy and most windy years, respectively, from this dataset; repeat your AEP calculation for each of these two years.

      i. How different are the windiest and 'weakest' years, respectively, compared to the mean you found above? What % AEP variation does this correspond to?

      ii. Your boss says that at their previous company, for uncertainty estimates they "*just used an inter-annual variability of 2 m/s for Denmark*". Given what you just found above for the windiest/calmest mean years, does this make sense? How do you respond to him/her about this?

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[1]E.g. see https://www.google.com/maps/place/The+Great+Belt+Bridge/

iii. A colleague does MCP analysis (long-term correction) on the long Sprogø data that you have here, based on a 50-year global re-analysis dataset at a resolution of $\sim$80 km; they say that *"your wind data seems like 30% too high"*. Is this reasonable? Whose number do you trust, and why? What quantity can you re-calculate, to again answer the previous question?

(c) Another colleague tells you that mesoscale modelling results of the Great Belt area (from WRF with 3 km grid-spacing, for 15 years) show that: for mean winds above 15m/s at $z = 110$ m, the geostrophic wind at Korsør differs from that at Nyborg, by an amount that increases linearly from 0% for $U|_{z=110m} = 15$m/s up to 10% for $U|_{z=110m}$ at cut-out. Your colleague is skeptical about the GDL, and claims that it thus can't be trusted for your analysis. What is your (numerically-based) response to this?

2. Estimate V_{50} at Sprogø (i.e. for $z = 70$ m), using three different methods.

(a) Use the results from one method, to then extrapolate the extremes from Sprogø to Nyborg and Korsør.

(b) How are the individual events at Nyborg different than those expected at Korsør? From which directions do the strongest winds 'blow' for each?

(c) Examine and discuss the results from the three methods you've used. Include which is best, and why...

(d) What would you do, if you only had only 1 year of measured data?

(e) What turbine class would you use at Sprogø? Would the Nyborg or Korsør sites require a different turbine class?