Topics:

1. Methods/Theory
   1. Topfarm
   2. Pywake
   3. Mesoscale models
2. Literature review
   1. K: focus more on layout
   2. A: focus more on seasonal variation

\section{Mesoscale model choice}

EWP %For the moment we are using the EWP, because we have used it in large wind farm clusters --> think of better reason. Use literature review paper

For the mesoscale analysis a choice has to be made between EWP and a fitch scheme. These two schemes differ in their recovery profile and their definition of the Turbulent Kinetic Energy. The EWP scheme exhibits a linear recovery of velocity behind the wind farm, while the Fitch scheme shows a rapid recovery in the near-wake followed by a slower recovery further downstream.

In this study, the EWP method is chosen for mesoscale wind farm modeling due to its demonstrated accuracy and efficiency in simulating wind turbine wakes and their interaction with the surrounding atmosphere, as highlighted in recent literature.

According to \cite{fischereit2022review}, EWP has emerged as a preferred approach for wind farm wake modeling because it offers a balance between computational efficiency and detailed representation of wake dynamics. This is particularly important for large-scale simulations that aim to capture the influence of wind farms on local atmospheric conditions without the computational overhead of more detailed models like Large Eddy Simulations (LES).

One key advantage of EWP is its ability to parameterize the wake effects based on the energy deficit approach, which is both computationally efficient and scalable for large wind farm arrays. As noted by \cite{fischereit2022review}, this method is able to integrate with mesoscale models, providing reliable predictions of wind farm performance across different weather conditions and topographies. Furthermore, EWP is particularly suitable for capturing the longer wake recovery distances observed under stable and near-neutral atmospheric conditions, where lower turbulence leads to slower wake recovery and larger wake effects. This makes it a robust tool for investigating the efficiency and potential energy output of wind farms under variable atmospheric conditions.

In conclusion, the EWP method was selected for its ability to provide a comprehensive yet computationally feasible model of wind farm wakes while incorporating key mesoscale atmospheric interactions, making it an ideal choice for this study’s objectives.

\section{EWP vs. Fitch Scheme: Justification for Choosing EWP}

While both the \textit{Energy-based Wake Parametrization} (EWP) and the \textit{Fitch scheme} are commonly used in mesoscale wind farm modeling, EWP was selected for this study due to several practical advantages, particularly when it comes to computational efficiency and the integration of large-scale atmospheric conditions.

One of the key reasons EWP is preferred over the Fitch scheme lies in its ability to model wake recovery over longer distances under stable and near-neutral atmospheric conditions. As described in the literature review by \cite{fischereit2022review}, stable atmospheric conditions lead to lower mixing of air layers, which in turn results in slower wake recovery. The Fitch scheme is a more simplified method that tends to provide reasonable results for general wake dynamics but does not capture the longer recovery times associated with stable conditions as effectively as EWP.

%Computational efficiency:

The Fitch scheme, while useful for simulating the wakes of individual turbines, is generally considered more computationally intensive when applied to large wind farms, especially in complex terrain or for large datasets. In contrast, EWP allows for efficient integration with mesoscale models because it uses a parameterization approach that focuses on the energy deficit in the wake, which can be easily scaled for large wind farm arrays and is much less computationally demanding. This efficiency is crucial when simulating the performance of large offshore wind farms, where mesoscale effects are significant, and where the computational cost of applying more detailed methods like the Fitch scheme becomes prohibitive.

The choice of Explicit Wake Parametrization (EWP) over the Fitch scheme is driven by key differences in their treatment of wake recovery and turbulence modeling, which are important for mesoscale simulations of wind farms under variable atmospheric conditions.

While the Fitch scheme (Fitch et al., 2012) introduces a turbine-induced drag based on the thrust coefficient of modern turbines and accounts for the variation in turbulence kinetic energy (TKE) with wind speed, it exhibits a rapid recovery of wind velocity in the near wake, followed by a slower recovery further downstream. This characteristic of the Fitch scheme, although useful in certain cases, does not accurately capture the linear recovery of velocity seen in the EWP scheme, which provides a more realistic representation of wake dynamics, particularly in unstable or neutral conditions. Additionally, the Fitch scheme assumes a simplified approach to turbulence, which may not be as suited for accurately modeling wake recovery in realistic atmospheric conditions.

In contrast, the EWP method, developed by Volker et al. (2015), offers a more nuanced definition of TKE, which better captures wake dynamics over longer distances. The linear recovery profile of EWP aligns more closely with observed wake recovery behavior, particularly in situations where turbulence is moderate and recovery occurs gradually, which is common under unstable or near-neutral conditions. Moreover, the EWP scheme’s detailed treatment of TKE and velocity profiles makes it a better fit for mesoscale simulations where these factors play a crucial role in determining wind farm efficiency.

Therefore, EWP was selected for this study due to its superior handling of wake recovery and turbulence dynamics in conditions relevant to the Indian site being modeled, where stable conditions are less frequent, and wind recovery profiles are more gradual.