Summary literature research

**Master Thesis Adit:**

Interaction between wind farms and atmosphere, effect of stability on the structure of velocity deficit regions or wakes.

Comparing modelled wind fields and wakes using two schemes (Explicit Wake Parametrisation (EWP) scheme and Fitch scheme) with satellite images and measurements, effect of atmospheric stability on wakes and power production.

**Meso wake pp:**

Overview with figures of done research and some explanations.

**Review of mesoscale wind-farm parameterizations and their applications**:

Literature review

**Making the Most of Offshore Wind: Re-Evaluating the Potential of Offshore Wind in the German North Sea:**

Capacity needed for reaching climate goals. The more turbines are installed in a region, the less efficient offshore wind production becomes due to a lack of wind recovery. So countries should cooperate in planning. Simulating wind reduction using 2 methods and estimating power for different capacities. Comparing methods.

**Prospects for generating electricity by large onshore and offshore wind farms:**

Simulation of wind speed field inside wind farms for varying sites and wind conditions, for neutral stability.

**Cluster wakes and their effect on a wind farm annual energy production:**

Validating different models on SCADA data. Normalised power per turbine for 2 wind farms.

**Assessing the wind energy technical potential of the North Sea:**

All build, planned and available wind farms in the north see. Simulation of no wakes, engineering wakes and mesoscale wake comparison for 4 and 8 W/m2.

**Climatological study of wakes from offshore wind farm clusters thesis Michael:**

Investigation of wake behaviour by 2 parameterization schemes in WRF model. Validation using measurements from FINO3.

**Simulating wake losses of the Danish Energy Island wind farm cluster:**

Comparing 5 methods on the Danish energy island. Energy output of about one of the ten wind farms is lost due to wind turbine and farm interaction. They recommend investigating different wind farm cluster layouts by using irregularly placed wind turbine positions

**Walle thesis**

Comparison wind farm alone vs in wake of other wind farm and squared wind farm investigation. Simplified wind rose for last one to have better understanding of simpler wind farm geometry and also location specific wind rose.

List of useful literature:

* P.J.H.Volker,J.Badger,A.N.Hahmann,andS.Ott.“TheExplicitWakeParametri sation V1.0: a wind farm parametrisation in the mesoscale model WRF”. In: Geosci. Model Dev. 8 (2015), pp. 3715–3731. URL: doi:10.5194/gmd-8-3715 2015: modelled the Horns Rev I wind farm in an idealised WRF simulation using the two wind farm parametrisation schemes, and validated the wind speeds downstream of Horns Rev I against two MET mast measurements at 2 km and 6 km from the turbines.
* Synthetic Aperture Radar (SAR) data to study downstream flow and wakes (if no metmast): Hasager, C. B., Furevik, B.R., Pryor, S.C., Barthelmie, R.J. “Offshore wind re sources quantified fromsatellite SAR: methodologyandtechnicalaspects”. In: Proceedings (2002), pp. 778–782.
* Velocity deficits of 2% up to 20km downstream of Horns Rev I wind farm for near-neutral stable atmospheric conditions and up to 5 km for unstable conditions (using SAR): Merete B. Christiansen, and Charlotte B. Hasager. “Wake effects of large off shore wind farms identified from satellite SAR”. In: Remote Sensing of Environ ment 98 (2005), pp. 251–268. URL: doi:10.1016/j.rse.2005.07.009.
* Measurements by research aircraft of velocity deficits at 5 and 45 km: Andreas Platis, Simon K. Siedersleben, Jens Bange, Astrid Lampert, Konrad Bärfuss, RudolfHankers,BeatrizCañadillas,RichardForeman,JohannesSchulz Stellenfleth, Bughsin Djath, Thomas Neumann & Stefan Emeis. “First in situ evidence of wakes in the far field behind offshore wind farms”. In: Scientific Reports 8:2163 (2018). URL: doi:10.1038/s41598-018-20389-y.
* Hahmann, Andrea N., Pena Diaz, Alfredo, and Hansen, Jens Carsten. “Im pact of atmospheric stability on X-band and C-band synthetic aperture radar imagery of offshore windpark wakes”. In: Journal of Renewable and Sustainable Energy 10 (2018), p. 043301. URL: doi:10.1063/1.5020437: quantified and characterized wakes based on wind speed, wind direction, and atmospheric stability, using SAR images for a wind farm in a cluster the North Sea.
* [The future of offshore wind power production: wake and climate impacts](https://arxiv.org/html/2408.14963v1?utm_source=chatgpt.com)
* [Indian-Danish collaboration launches conceptual plan for 15 Indian offshore wind parks](https://ens.dk/en/press/indian-danish-collaboration-launches-conceptual-plan-15-indian-offshore-wind-parks)
* [Offshore Wind | MINISTRY OF NEW AND RENEWABLE ENERGY | India](https://mnre.gov.in/en/off-shore-wind/)
* [2022121964.pdf](https://cdnbbsr.s3waas.gov.in/s3716e1b8c6cd17b771da77391355749f3/uploads/2022/12/2022121964.pdf)
* [Wake flow in a wind farm during a diurnal cycle: Journal of Turbulence: Vol 17 , No 4 - Get Access](https://www.tandfonline.com/doi/full/10.1080/14685248.2015.1127379)

About weather/ wind south of India:

* [Offshore Wind Potential in South India from Synthetic Aperture Radar](https://backend.orbit.dtu.dk/ws/portalfiles/portal/7749647/ris_r_1780.pdf) DTU 2011
* [Full article: Assessment of wind and wave energy potential along the Indian coast](https://www.tandfonline.com/doi/full/10.1080/23311916.2024.2316950?utm_source=chatgpt.com#d1e276) general wind speed data along the coast of India
* [Exploring the Offshore Wind Resource Potential of India Based on Remotely Sensed Wind Field Data | Request PDF](https://www.researchgate.net/publication/360530263_Exploring_the_Offshore_Wind_Resource_Potential_of_India_Based_on_Remotely_Sensed_Wind_Field_Data) looks at India's offshore wind resource potential using ASCAT wind speed observations from 2007 onwards. Provides insights into wind speed distributions and identifies areas with significant offshore wind energy potential. Finds Tamil Nadu is (southern part of India so the potential location) as best option for a wind farm along the Indian coast. Dominant wind direction is NE at southern site in summer. NW in winter.

Important things learned:

* Stable (and near neutral) conditions have lower mixing of air layers, and so wakes (and wind velocity slowed down) recovers over a longer distance than in unstable conditions.
* Microscale = within wind farm  
  Mesoscale = measure of large new offshore wind farm  
  Synaptic/ global scale = climate models

Tools usable:

* Running Weather and Research Forecasting (WRF) model with; Fitch scheme or Explicit Wake Parameterization (EWP)
* Engineering wake models: Gaussian, park model
* Higher fidelity wake models: LES, CFD, RANs simulations
* FUGA: linearized CFD model, microscale. Constructred by set of mixed-spectral equations and lookup tables to store the pre-calculated results (so faster than traditional CFD models). Uses WasP as input for turbines en terrain etc.

Prognostic models simulate atmospheric conditions over time (EWP).

The fitch and EWP differ in rate of velocity deficit and rate of wake recovery, but almost end up at same point.

Terms:

* **Barotropic**: no T variation with height, wind mostly depends on pressure differences.
* **Baroclinic**: T changes with height, causing more turbulent and stronger wind gradients. Change of pressure when you go up will be different
* **Weak inversion**: small T difference between layers, so milder wind changes.
* **Strong inversion**: big T difference between layers, which restricts vertical mixing and can create stronger wind variations.
* **Parameterization**: simplifying of eg a wind farm
* **Near wake**: depends mainly on blade aerodynamics just behind rotor. Length of around one rotor diameter.  
  **Far wake**: starts where the flow is roughly governed by turbulence shear mixing. It continues expanding by a turbulent diffusion process between the environmental flow and the velocity deficit region. (Walle thesis).

Wind/ weather south of india:

* [Hot Weather Season in India](https://www.nextias.com/blog/hot-weather-season-in-india/#:~:text=In%20conclusion%2C%20the%20hot%20weather,cyclones%20that%20affect%20coastal%20areas.)
* [SouthWest Monsoon in India: Features, Theories & Mechanism](https://www.nextias.com/blog/southwest-monsoon-in-india/)
* [A seasonal prevailing wind in the region of South and SE Asia, blowing... | Download Scientific Diagram](https://www.researchgate.net/figure/A-seasonal-prevailing-wind-in-the-region-of-South-and-SE-Asia-blowing-from-the_fig5_366840015) from SW between May and September (plus rain, wet monsoon) and from the NE between October and April (dry monsoon). So this would be from complete opposite directions and thus seems that is cannot be optimized for summer or winter.
* [Satellite Based Interpretation of Stability Parameters on Convective Systems over India and Srilanka | Asian Journal of Atmospheric Environment](https://link.springer.com/article/10.5572/ajae.2020.14.2.119)
* [Synoptic systems and weather | SpringerLink](https://link.springer.com/chapter/10.1007/3-540-37722-0_4) book the Asian monsoon ch4
* [Intra-seasonal variability in Oceansat-2 scatterometer sea-surface winds over the Indian summer monsoon region | Meteorology and Atmospheric Physics](https://link.springer.com/article/10.1007/s00703-012-0189-5)\
* [Assessment of wind energy potential over India using high-resolution global reanalysis data | Journal of Earth System Science](https://link.springer.com/article/10.1007/s12040-021-01557-7) but more over potential on land
* [Global surface temperature in relation to Northeast Monsoon Rainfall over Tamil Nadu](https://www.researchgate.net/publication/225644764_Global_surface_temperature_in_relation_to_Northeast_Monsoon_Rainfall_over_Tamil_Nadu) The northeast monsoon (October to December) is crucial for rainfall in Tamil Nadu. Studies have shown that global surface temperature anomalies influence the variability of monsoon rainfall in this region
* [How is Climate Change Altering India’s Monsoon Rainfall Patterns?](https://www.ceew.in/publications/decoding-changing-monsoon-rainfall-patterns-due-to-climate-change-in-india) Decoding India’s Changing Monsoon Patterns
* [Offshore Wind | MINISTRY OF NEW AND RENEWABLE ENERGY | India](https://mnre.gov.in/en/off-shore-wind/)

What can I do:

* Begin latex document (they send format)
* List all models/tools/simulators with citation
* Try to change mean in practice Jupiter file to mean for summer and winter
* Lees andere master thesis and form introduction in similar style with research questions etc
* Wd and stability plots maken voor November-march as winter and April to October as summer season.

Objectives for next 2 weeks (mid-march):

1. Exploring and describing the TN wind farm related climate
   1. Defining seasons, what literature has already looked at this
   2. Ways to describe the climate experienced across the wind farms within the cluster (plots per month with windroses and windroses for stability).
   3. Breaking down the seasonal or monthly characteristics

Based on Case 0 mesoscale data, analysis and literature

1. Getting acquainted with PyWake Topfarm to get comfortable with creating tests and analysing results
   1. Creating an idealized wind farm cluster with 3 wind farms (perhaps a simplified version of 1,2,3 from TN wind farm cluster),
   2. Creating “mock” dataset of wind speeds, direction and TI, based on random perturbation from “sensible” mean values, later to be tied to season characteristics
   3. And then running these to create optimized layouts for the 3 wind farms in the idealized cluster
   4. Extend to replacing the “mock” data with suitable data from the mesoscale runs (case 0)
2. Thinking the hypothesis and tests combining Topfarm outcomes and WRF mesoscale.

Riso 3 april:

* Right overleaf?
* Implementing right wind conditions in idealized wind farm
* Set defense date
* Turbine conditions for th background

Meeting martin 15 april:

* Blockage not necessary
* Don’t go to much into detail with options not using
* Longer paragraph about methods actually using.
* He writes wakes models developed in the 80s etc
* Pywake/ foxes and one other similar tools (fox developed by Oldenburg)
* He sends paper about comparison of tools

Oscar provides layout with grid size and specifications

Ideal layout 3 WF of each 1GW, about 15x15km. 66 turbinesx15MW

Idealized also in both pywake and mesoscale

Mesoscale domain of 100x100km and dx=2km

Take average April-oktober and winter and put perturbation on that. Run topfarm idealized layout on that.

Adjoint (automatic differentiation). Faster to find optimization than evaluation because only using gradiants and evaluations calculates full AEP with all parameters. Explain use Julians paper that he sent last time, this is about that.

Helpful sites:

* [Tips for Students | HRI Wiki](https://hri-wiki.tudelft.nl/home/student-info/tips)
* [APA 7th Citation Examples](https://www.tudelft.nl/tulib/apa-citation-examples)
* [Making a search plan](https://www.tudelft.nl/tulib/searching-resources/making-a-search-plan)
* [Basic Visualization](https://tutorial.xarray.dev/fundamentals/04.1_basic_plotting.html): how to plot
* [Experiment: Combine Models — PyWake 2.6.8.dev23+gf8bfe4e7 documentation](https://topfarm.pages.windenergy.dtu.dk/PyWake/notebooks/exercises/CombineModels.html) pywake tutorials
* [Design variables — TOPFARM 2.5.0.post4 documentation](https://topfarm.pages.windenergy.dtu.dk/TopFarm2/notebooks/design_variables.html) Topfarm tutorials. ‘Layout optimization with SGD driver – compares SLSQP with SGD.

Martin 1st of mai gone and 17th of april

|  |  |  |  |
| --- | --- | --- | --- |
| Wind farm | Turbine | Total | Foundation |
| Borsele I+II | 94x Siemens Gamesa 8 MW | 752MW | Monopiles in 14-36m |
| HKN | 69x Siemens Gamesa 11MW | 759MW |  |
| HKZ | 139x SG 11MW | 1529 MW |  |
| Gemini | 150x 4 MW | 600 MW | Monopiles in 28-36m |
| Hornsea 1 | 174x 7 MW | 1218 | Monopiles |
| Doggerbank |  |  |  |

|  |  |  |
| --- | --- | --- |
| 15-22 Jan | Reading papers |  |
| 23 Jan | Meeting at Riso, thinking about possible narrowed down topics |  |
| 24 Jan | Formulating topic options, finding help sources, reading extra paper |  |
| Ma 27 jan | Setting up environment, downloading pywake and trying exercises. Also set up Jupiter notebook. |  |
| Tu 28 jan | Reading last paper, finding papers about weather in india. |  |
| We 29 jan | Creating correct environment, doing xarray tutorials |  |
| Th 30 jan | Xarray tutorials |  |
| Fr 31 jan | Making latex, summing up methods. |  |
| Ma 3 feb | Finding literature for latex bib |  |
| Tu 4 feb | Explanding topic options |  |

Rare plots:  
