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Mesoscale/Microscale and CFD Modeling for Wind Resource Assessment: Application to the Andaman Coast of Southern Thailand

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ปัญญา จริยธรรม นำการพัฒนา

Topics

- Introduction
- Objective
- Methodology
- Results and Discussion
- Conclusion
- Acknowledgements

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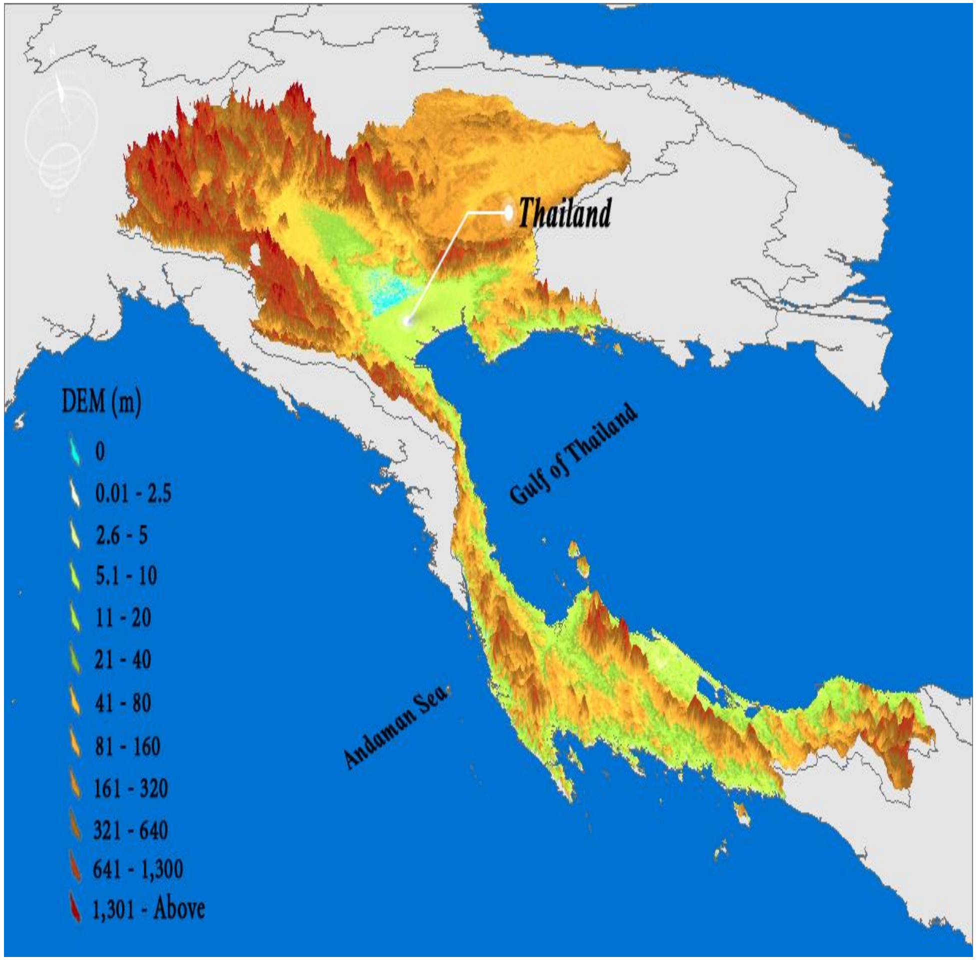
Introduction

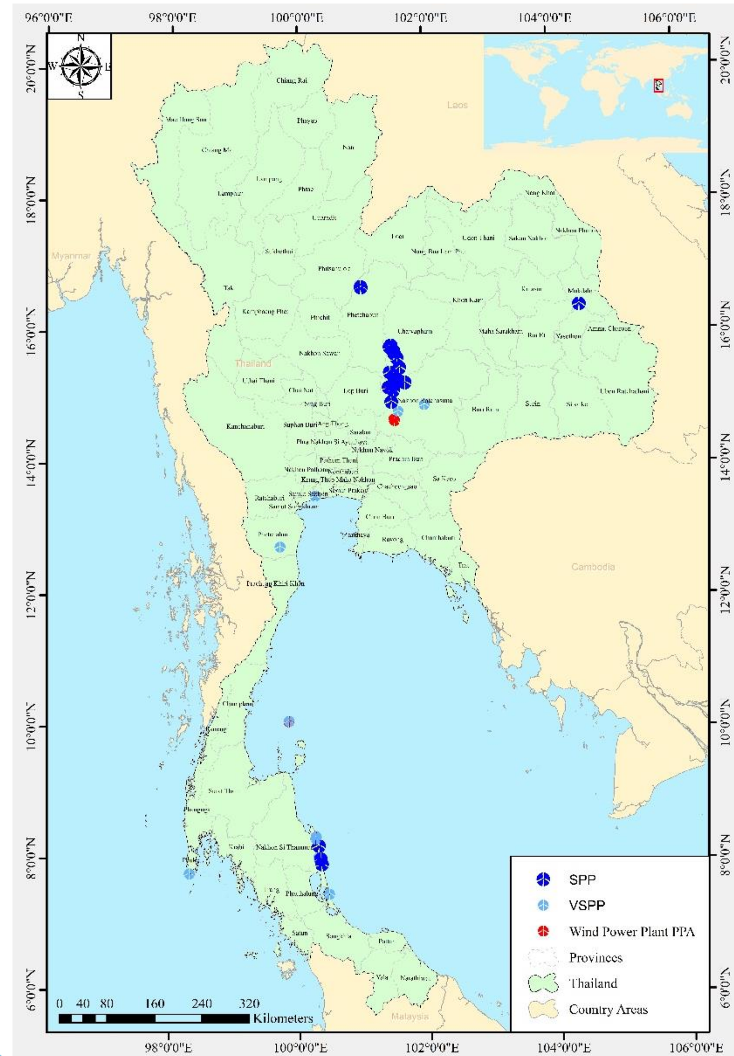
- Since 2004, Thailand has been among the forerunners in Asia in promoting alternative energy development via government policies and investment incentives.
- In early 2019, the national Power Development Plan (PDP) and the Alternative Energy Development Plan (AEDP) were approved, marking the continuation of this trend.
- Renewable energy in Thailand is projected to be 30% of the total energy production by 2037, jumping from the current 14.5%, with big Thailand state-owned and private-sector conglomerates taking the lead.

Introduction

- The Power Development Plan (PDP) is expected to be updated again soon of the 29.4 GW which was allocated to the renewable energy in the latest PDP update early this year, the quota proportions for each type of renewable energy is as follows (including existing and new capacity by 2037):
  - Solar: 15,574 MW
  - Biomass: 5,786 MW
  - Wind: 2,989 MW
  - Biogas: 928 MW
  - Municipal solid waste: 900 MW
  - Industrial waste: 75 MW
  - Small hydro: 188 MW
  - Large hydro: 2,918 MW

Introduction





Objective

- To develop a microscale wind resource map
  - spatial resolution of 200 m (200 m × 200 m grids) for low to moderate wind areas and
  - spatial resolution of 50 m for the most promising areas of the western coast of Southern Thailand

Methodology

- ❑ Study Area and Characteristics
- ❑ Mesoscale/Microscale Modeling
- ❑ CFD Wind Flow Modeling
- ❑ Wind Map Validation
- ❑ WTG Selection (AEP & C.F.)
- ❑ WTG Parking Optimization

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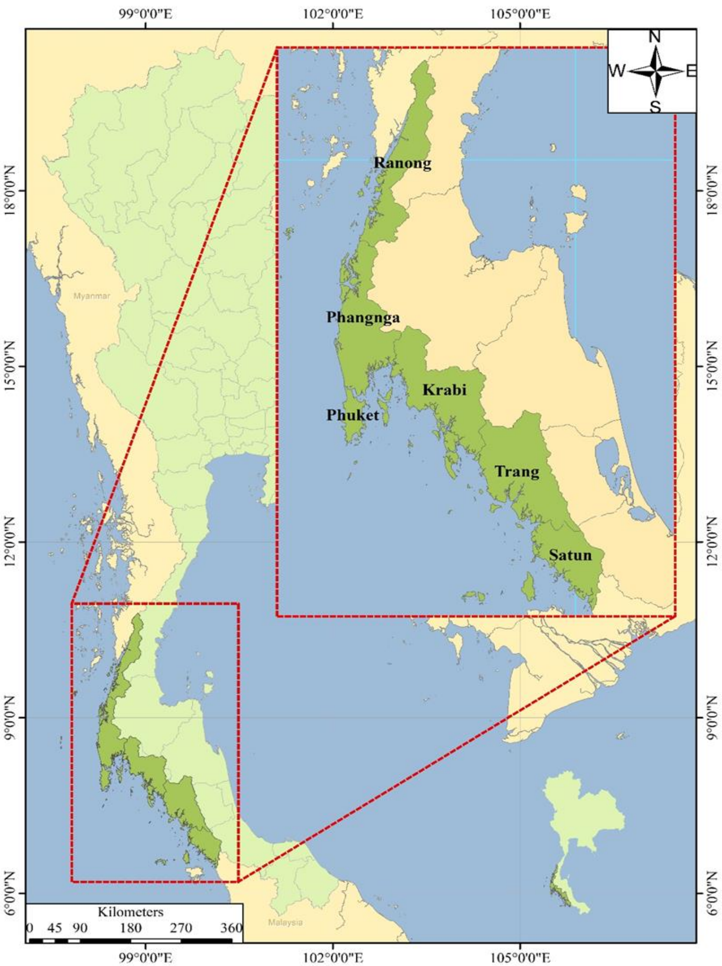
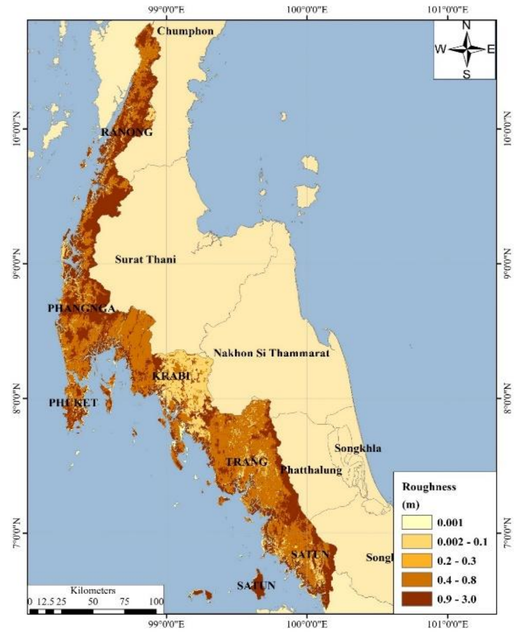
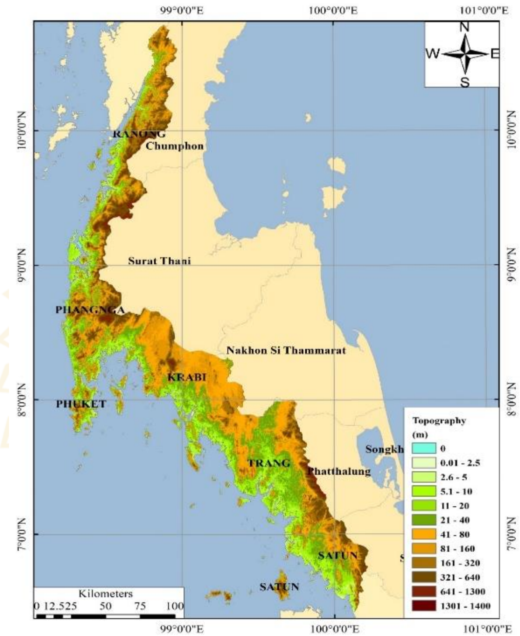
Study Area & Characteristics



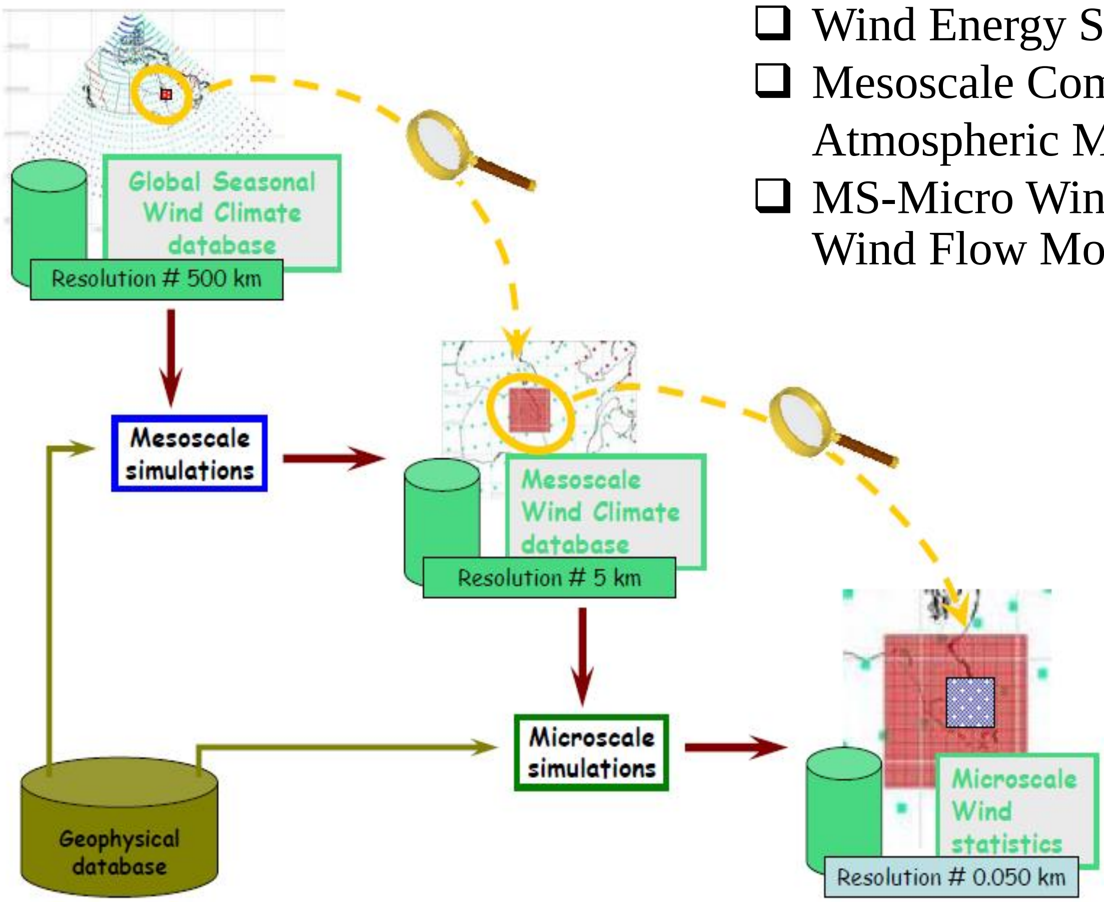




- ❑ Six provinces: Ranong, Phangnga, Phuket, Krabi, Trang and Satun
- ❑ The total area of 17,689 km^2 (24% of the area of Southern Thailand)
- ❑ Coastal mountains on land and a near shore area dotted with continental islands and barrier islands scattered along the Andaman Coast

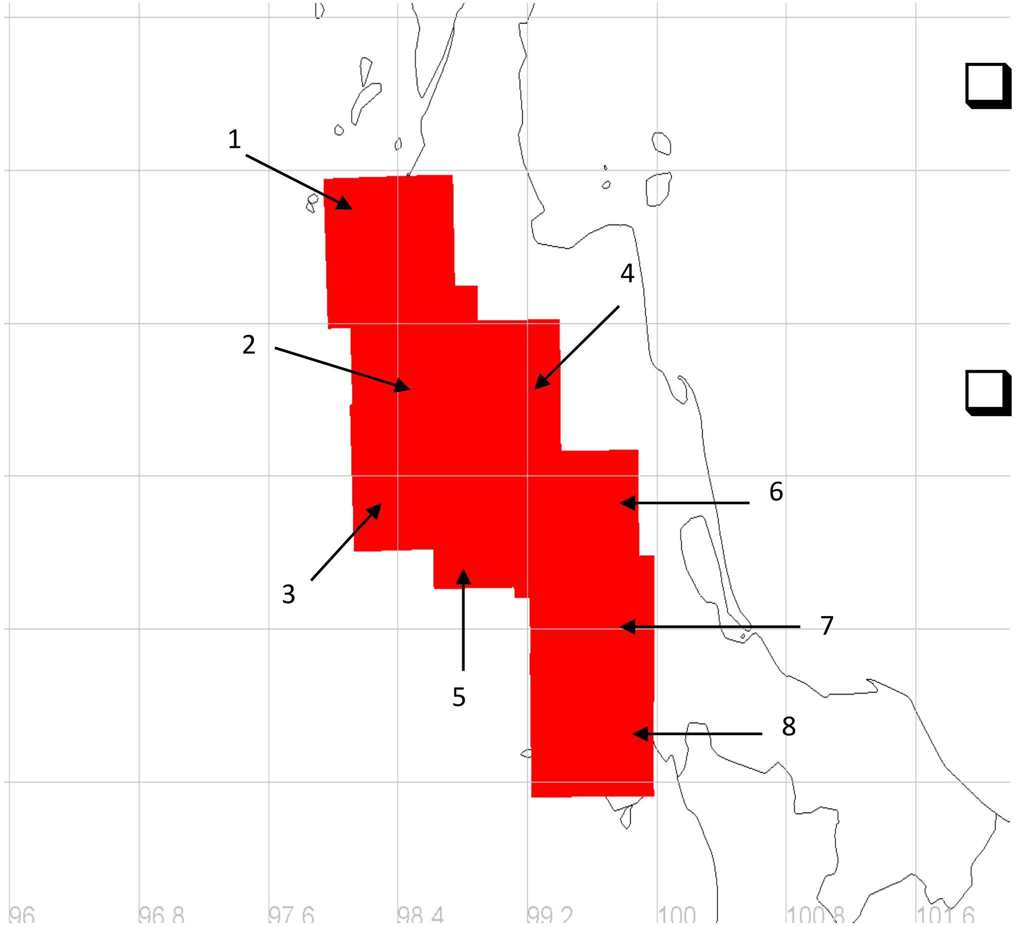
Mesoscale/Microscale Modeling

- ❑ Wind Energy Simulation Toolkit (WEST)
- ❑ Mesoscale Compressible Community (MC2) Atmospheric Modeling
- ❑ MS-Micro Wind Flow Modeling (Linearized Wind Flow Modeling)



- ❑ Inputs
  - ❑ MERRA-2 (1980-2014)
  - ❑ GDEM (Res 30 m)
  - ❑ Hi-res LULC (LDD)
- ❑ Outputs
  - ❑ Mesoscale spatial wind resource data @ 100, 120 m & 140 m AGL.
  - ❑ Microscale spatial wind resource data @ 100, 120, and 140 m AGL.

Mesoscale/Microscale Modeling



- ❑ Mesoscale Modeling
  - ❑ 8 Mesoscale Grids
  - ❑ 20% Grid Overlapping
  - ❑ Resolution 3 km
- ❑ Microscale Modeling
  - ❑ 14 Microscale Grids
  - ❑ 20% Grid Overlapping
  - ❑ Resolution 200 m

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CFD Wind Flow Modeling

Properties

1: Terrain extension	
Coordinate system	Global
X-range	**769346; 779546**
Y-range	**1634991; 1645191**
Projection	**NONE _WGS_84 0**
2: Roughness	
Roughness height	Read from grid.gws
3: Numerical model	
Automatic gridding	False
Refinement type	No refinement
Height above terrain	Automatic
Maximum number of cells	**3000000**
Height distribution factor	0.1
Orthogonalize 3-D grid	False
Number of cells in Z direction	20

Coordinate system
The coordinate system as defined in the grid.gws file

4: Smoothing	
Smoothing type	No smoothing
5: Forest	
Forest	Disregard forest

Coordinate system
The coordinate system as defined in the grid.gws file

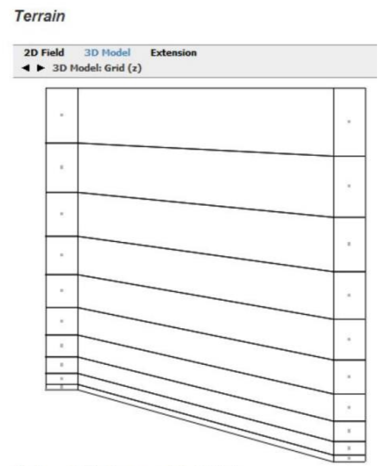


Fig 1. Digital terrain model - Grid (z).

Properties

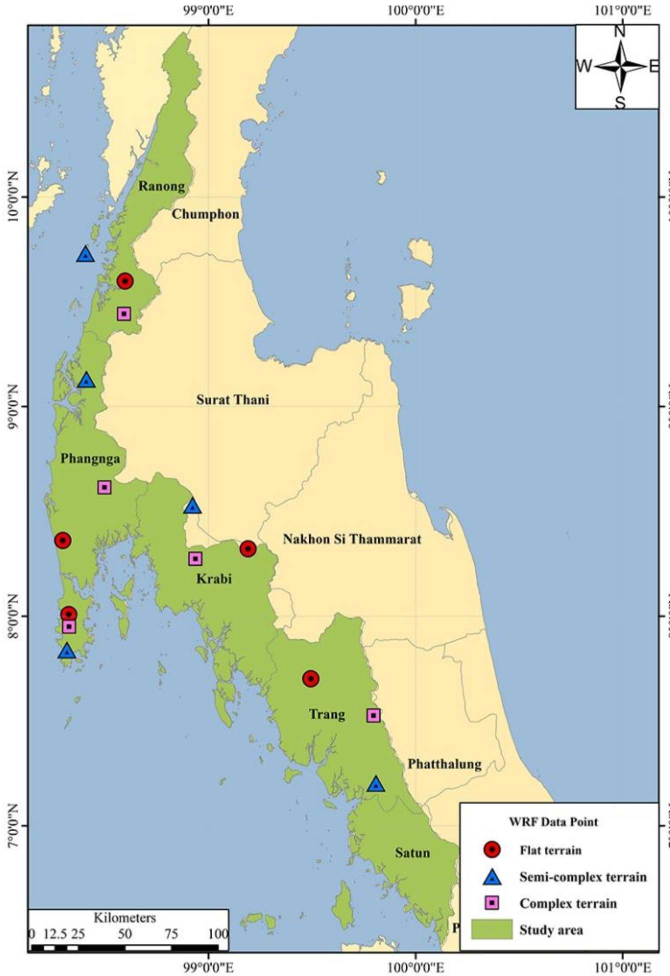
1: Boundary and initial conditions	
Do Nesting	Disregard nesting
Sector input type	Uniform distribution of the sector angl
Number of sectors	**16**
Sectors for next run	0;22;45;67;90;112;135;157;180;202;
Height of boundary layer	500
Speed above boundary layer he	10
Use previous run as input	False
Boundary condition at top	Fixed pressure
2: Physical models	
Potential temperature	Disregard temperature
Air density	1.225
Turbulence model	Standard k-epsilon
3: Calculation parameters	
Solver	GCV

Sectors for next run
The sector angles [0,359] (deg) for which wind-field data should be generated. Enter the sector angles as a list of numbers, separated by ';'...

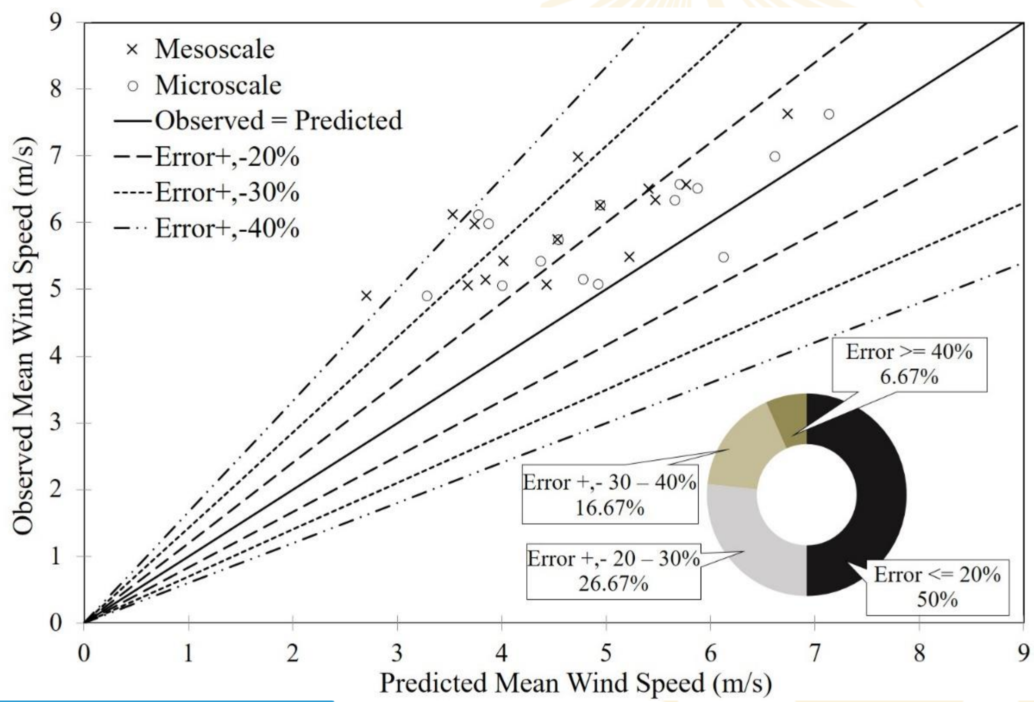
Properties

Solver	GCV
Number of simultaneous sector	1
Number of iterations	**1000**
Convergence wizard	False
Convergence criteria	0.005
4: Convergence monitoring	
Coordinate system	**Global**
Spot value X position	**774446**
Spot value Y position	**1640091**
Spot value Z position	**80**
Field value to monitor	Speed scalar XYZ
5: Output	
Height of reduced wind databas	300
Run in batch mode	False

Wind Map Validation



- Comparison of WRF atmospheric modeling (3TIER product)
- 3 Terrain Features: Flat, Semi-Complex, and Complex Terrains



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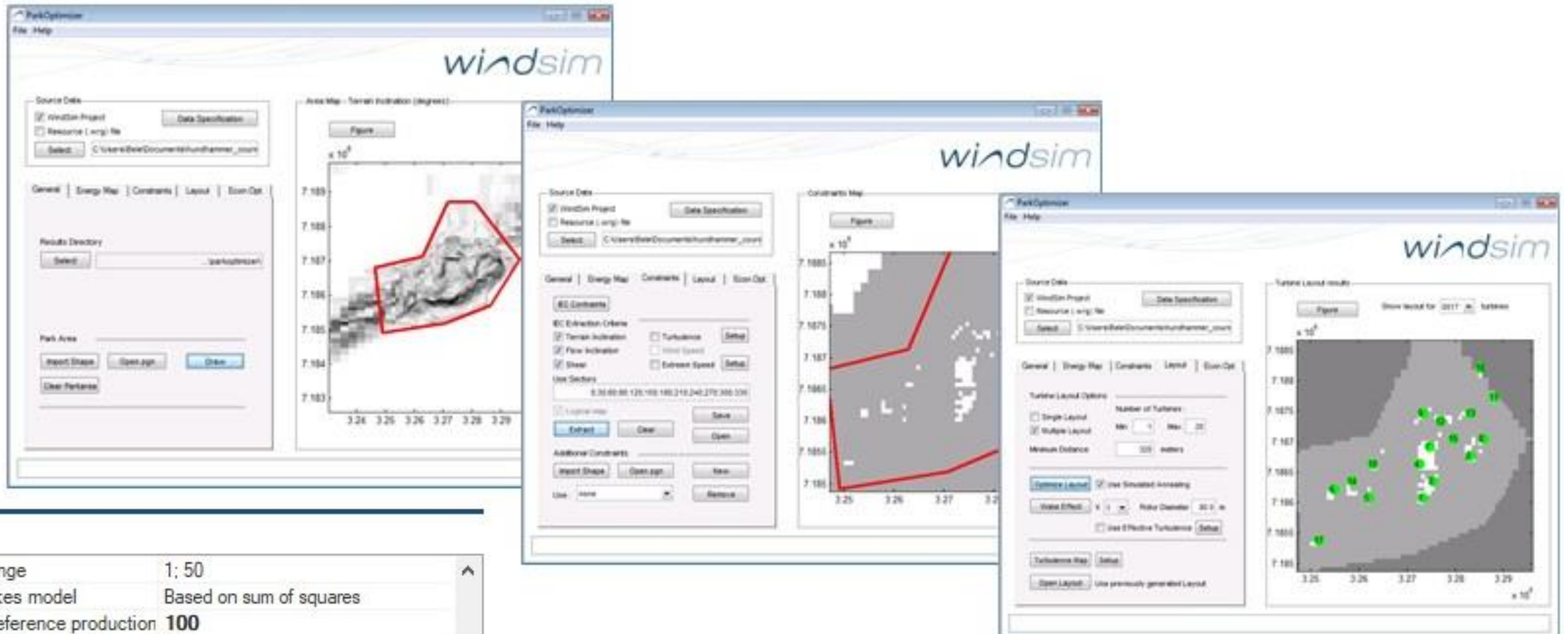
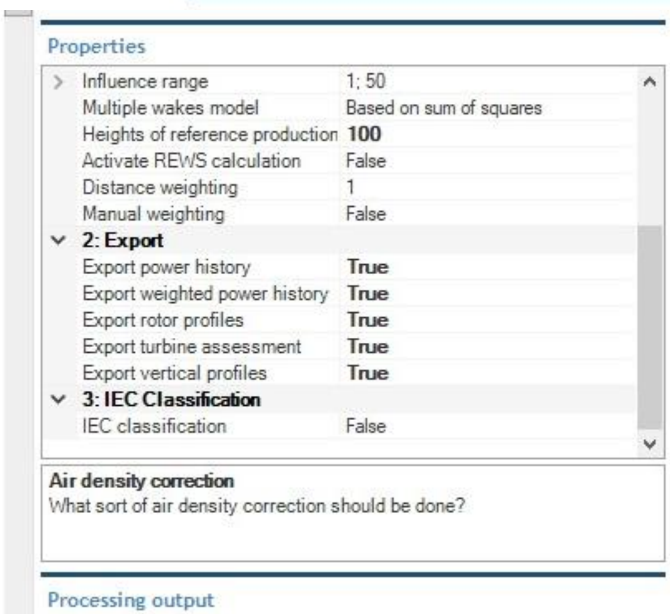
WTG Selection

No.	Wind Turbine Generator Model	Hub Height (m)	Rotor Diameter (m)	Rated Capacity (MW)	Cut-in Speed (m/s)	Rated Speed (m/s)	Cut-out Speed (m/s)
1.	GE 2.5	120	120	2.5	3.0	11.0	21.0
2.	G114	125	114	2.0	3.0	12.5	25.0
3.	GW2.5	120	121	2.5	3.5	11.0	22.0
4.	S111-M90	120	111	2.1	3.0	10.5	21.0
5.	V110-2.0	125	110	2.0	3.0	10.5	20.0

- ❑ Very Small Power Producer (VSPP) <= 10 MW/Power Plant
- ❑ Annual Energy Production (GWh/year)
- ❑ Capacity Factor (%)
- ❑ Wake Loss (%): (1) N.O. Jensen, (2) Larsen, and (3) Ishihara

WTG Parking Optimization





- ❑ The WTG with the highest AEP is then used for WTG parking optimization in order to
  - ❑ Minimize Wake Loss
  - ❑ Maximize AEP

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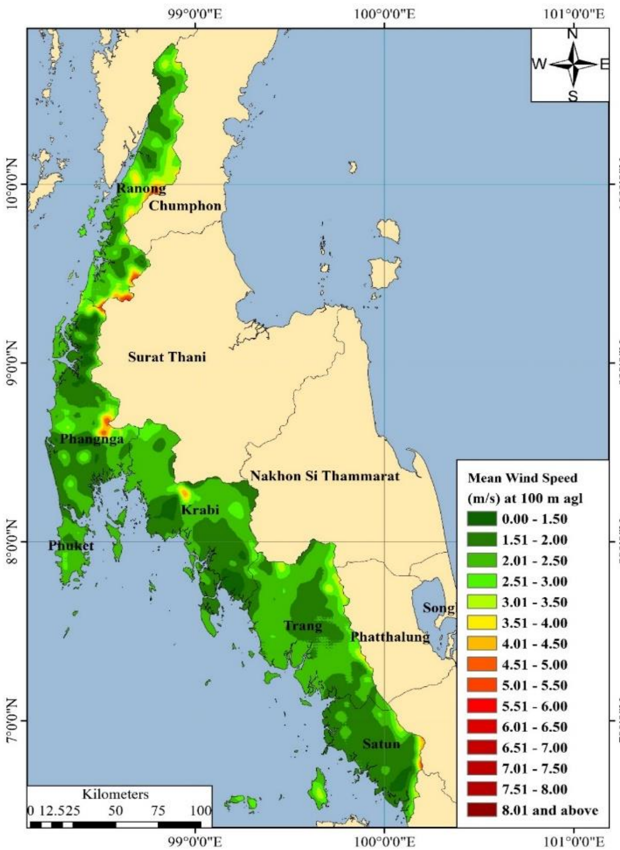
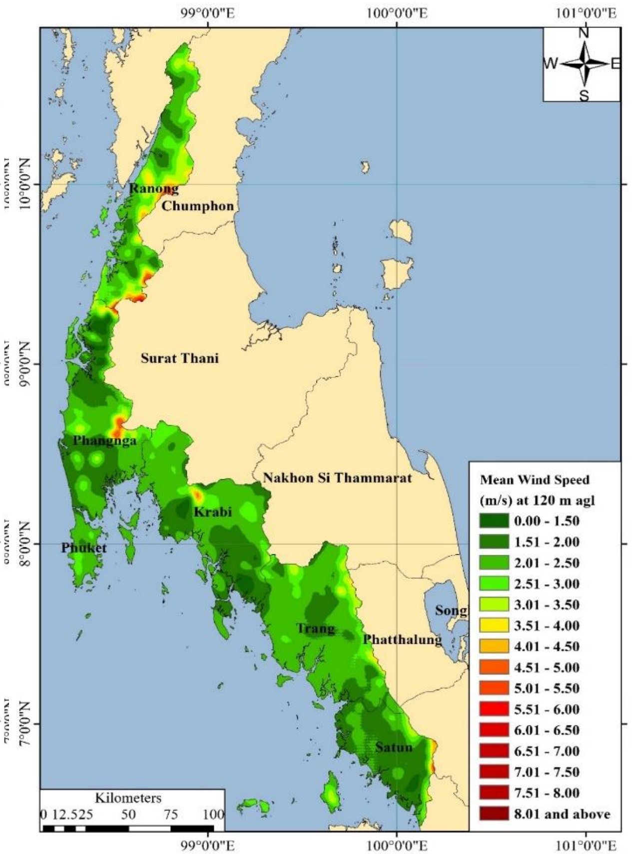
Results and Discussion

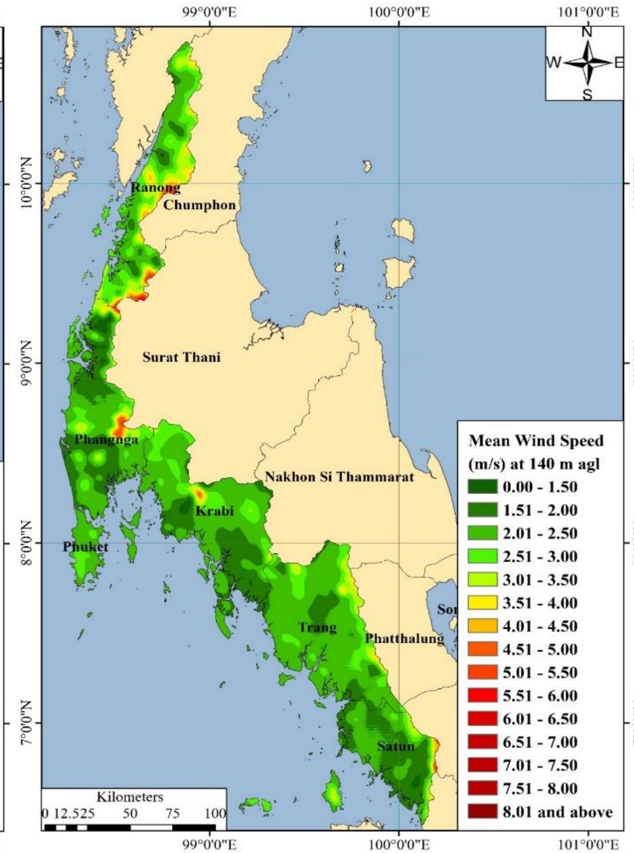
High Resolution Wind Resource Maps



100 m AGL.

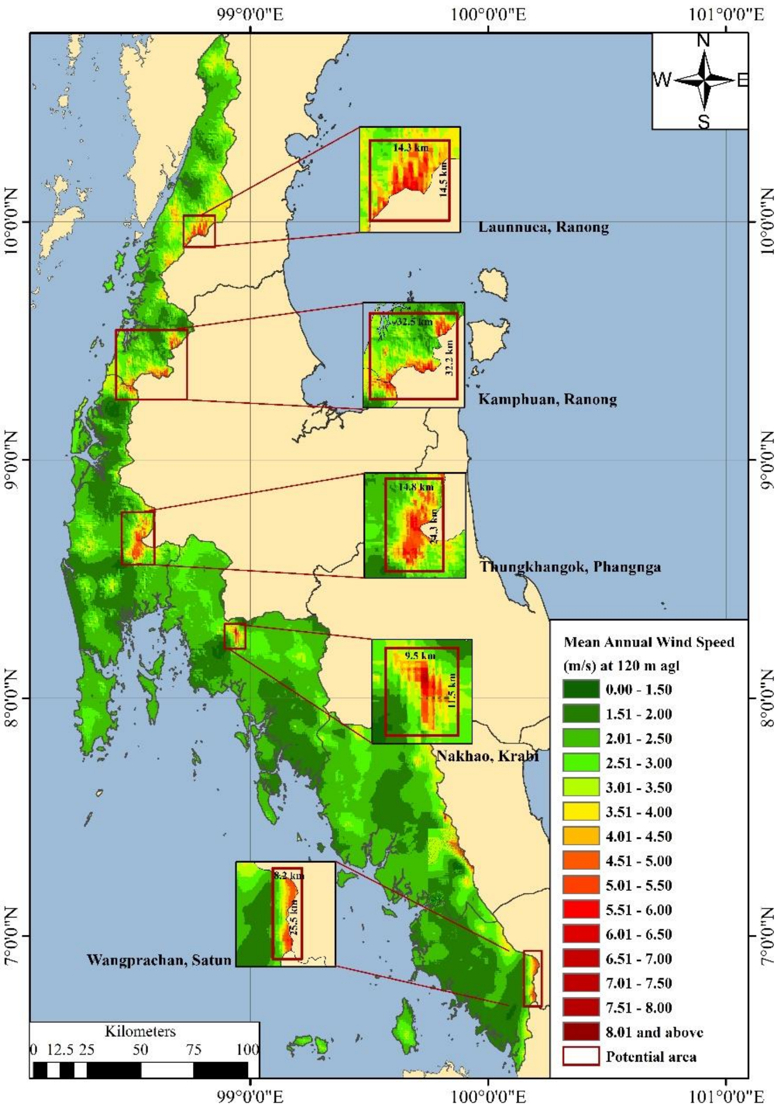


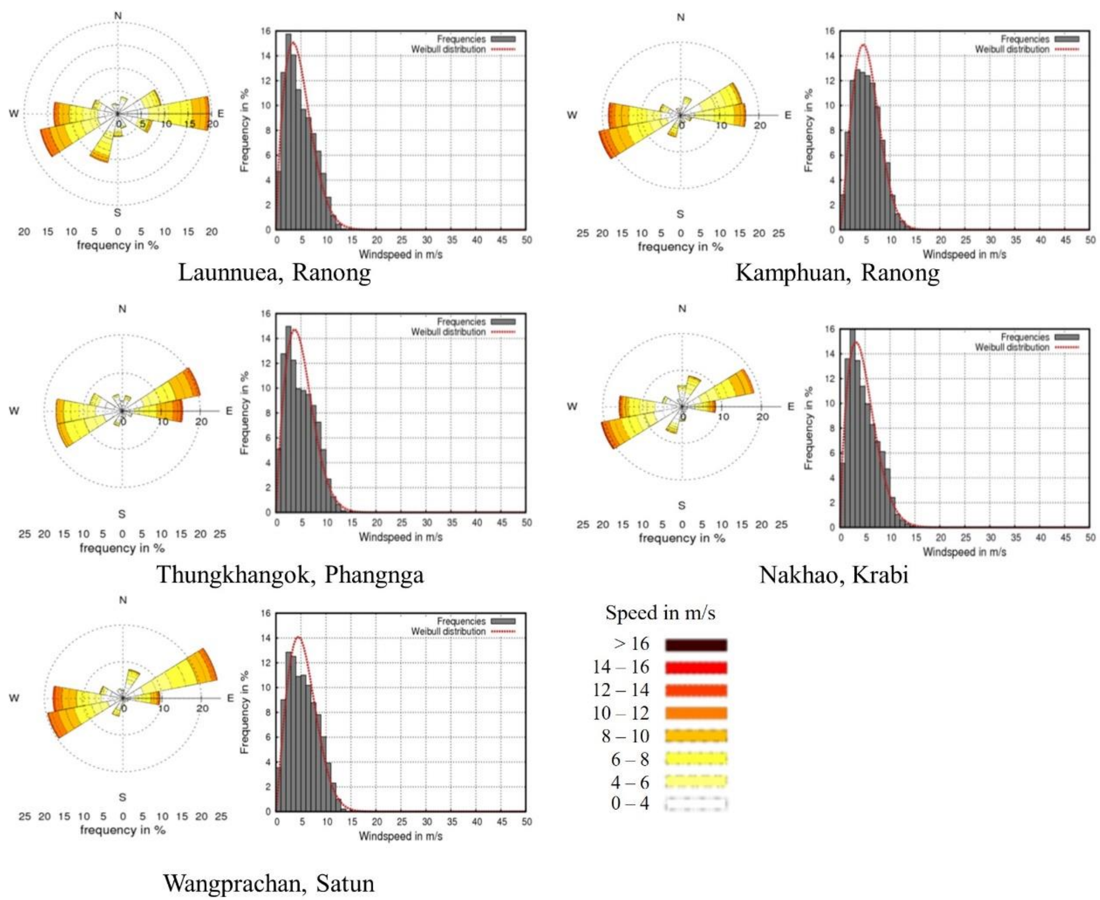
120 m AGL.



140 m AGL.

Results and Discussion





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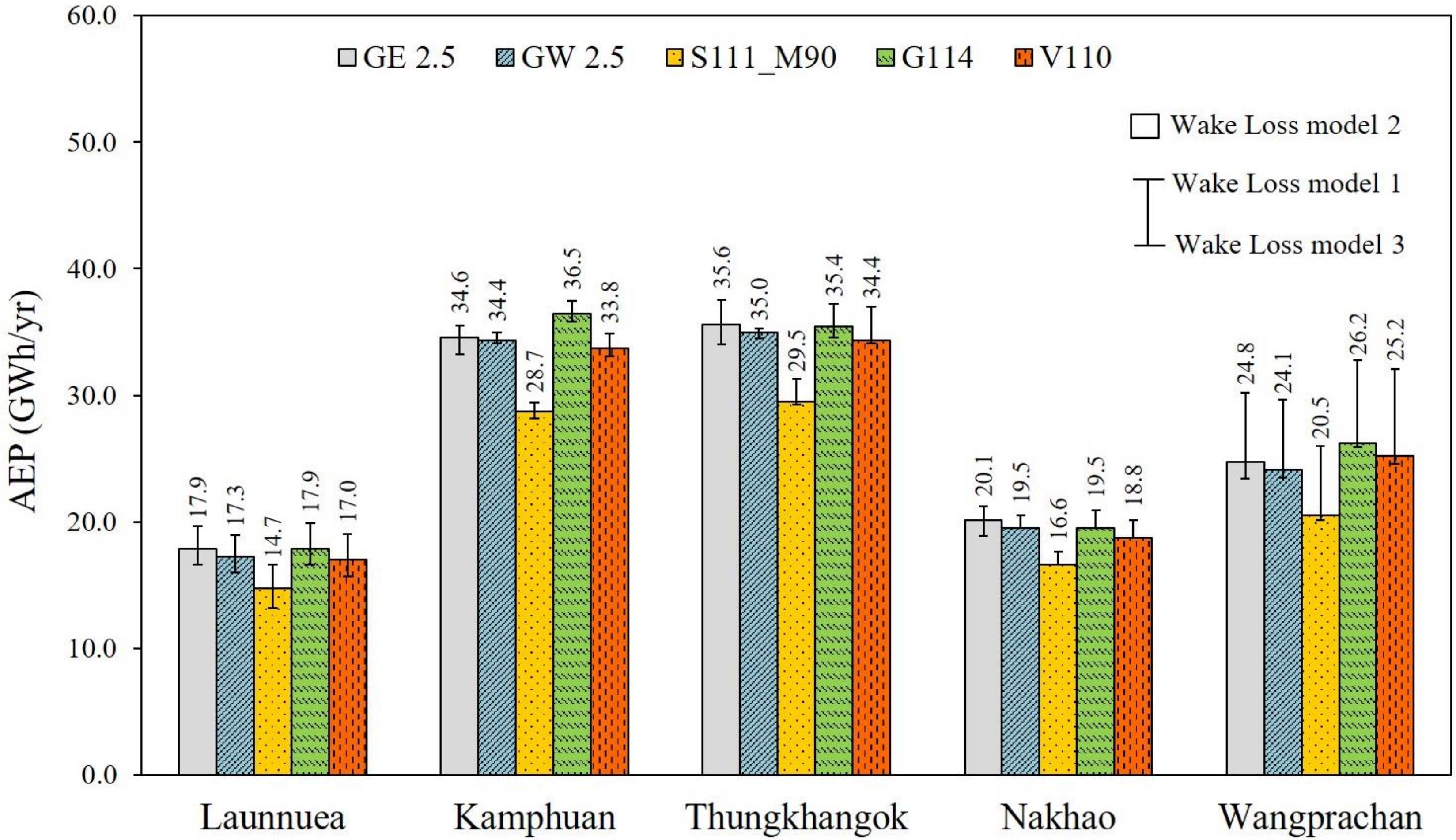
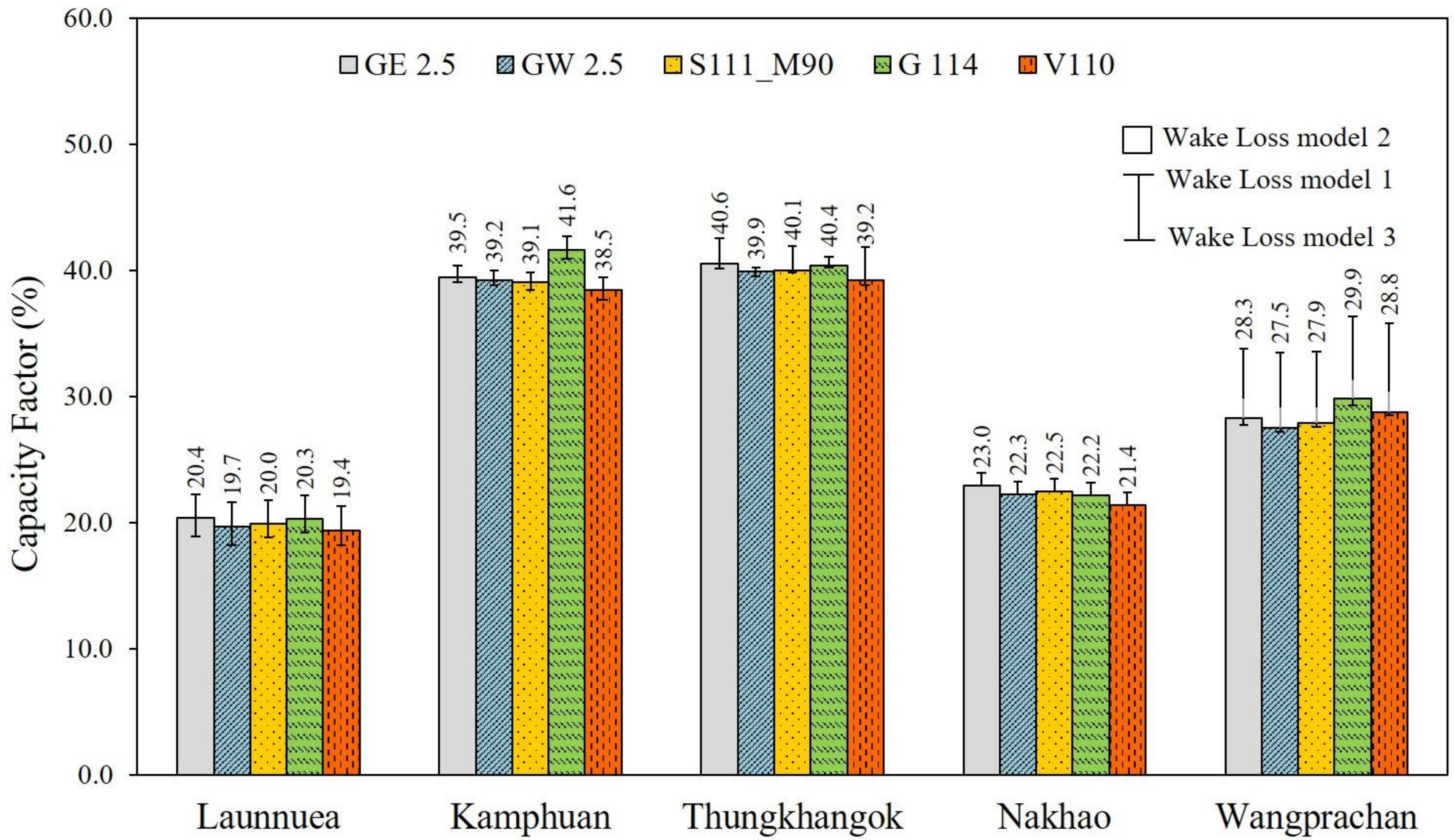
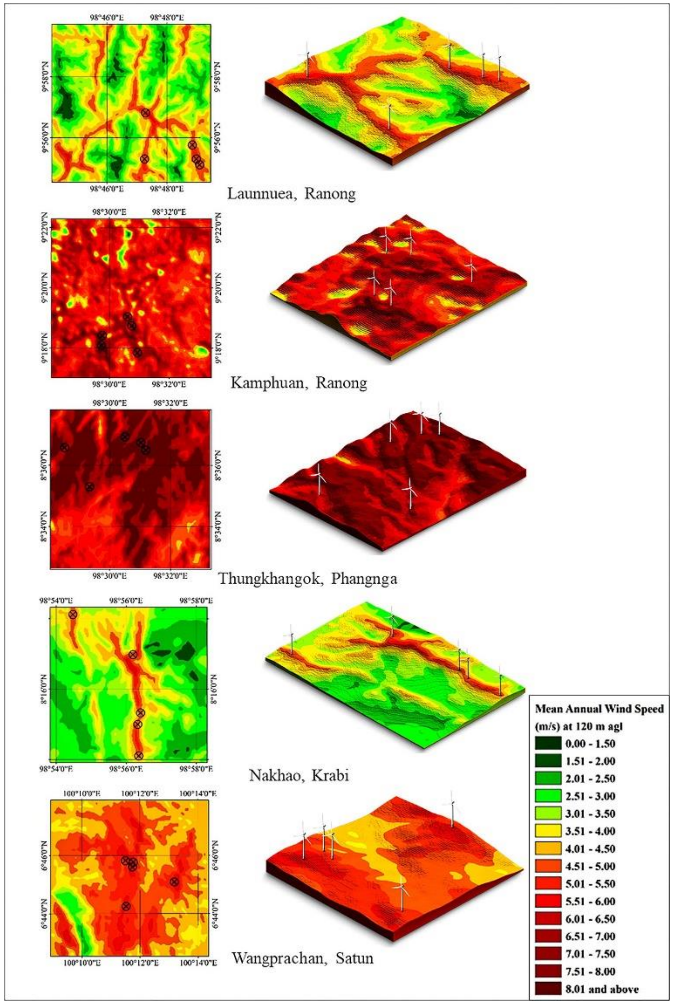
Results and Discussion



Results and Discussion



Results and Discussion



Conclusion

- A wind resource assessment on the Andaman coast of Thailand is executed based on a coupled mesoscale/microscale wind modeling, along with CFD modeling, to assess the wind resource and to estimate the annual energy production of five potential sites for wind power development.
- High-resolution microscale wind resource maps have been produced to assess the wind resource on the western coast of southern Thailand, on the Andaman Sea, and covering the provinces of Ranong, Phangnga, Phuket, Krabi, Trang and Satun.
- The AEP of sitting optimized wind power plants, including their capacity factors, are also estimated using CFD modeling.
- The parameters for the input data included the MERRA wind climatic database, along with high-resolution topography and LULC digital data.
- The results show that, at 120 m AGL., the predicted wind speeds from the model proposed are 20% lower for the mesoscale model, and 10% lower for the microscale model, in comparison to the equivalent wind speeds obtained from the WRF model.

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Conclusion

- Results from the microscale wind resource maps show that the western coast of Thailand is characterized by limited wind resources for power generation.
- Nonetheless, localized areas of Launnuea and Kamphuan in Ranong province, Thungkhangok in Phangnga province, Nakhao in Krabi province, as well as Wangprachan in Satun province, have potentials for wind power developments, notably at the small-scale level.
- The five potential sites identified for wind power development, using 10 MW VSPP, could attain capacity factors of over 20% for all the five sites identified, while two sites (Thungkhangok and the Kamphuan) could reach capacity factors of 40%.
- The annual energy productions for these sites would range from the lowest production (18 GWh/yr in Launnuea; 19 GWh/yr in Nakhao) to the largest production (36 GWh/yr in Kamphuan; 35 GWh/yr in Thungkhangok), with Wangprachan (26 GWh/yr) in the middle range.
- The total AEP would be in the vicinity of 135 GWh/yr when using a single wind turbine generator model for the five sites studied.

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Acknowledgements

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Publication

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Thank You for Your Attention

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