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Topographic Data Analysis of Observed Wind Data Recorded at 15 Different Stations in Thailand

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ABSTRACT

This study focuses on the collection and observation of mean wind speed and power density of 15 stations in Thailand merged with the topographic map of the stations. The wind data was collected by installing anemometers at 10m, 15m, 20m,25m and 30m height at 15 selected stations around Thailand. Wind Analysis and Application Program (WAsP) is used to generate mean wind speed and power density. Meanwhile, roughness and surface elevation map are produced and merged with the data in WAsP. The results showed the highest wind speed in Songkhla station which was 3.16 to 12.15m/s and on the other hand data from Narathiwat showed the lowest mean wind ranging from 1.13 to 1.72m/s. Finally, Songkhla station power density ranges from 24-1372W/m^2 and in Narathiwat station ranging from 2-5W/m^2 in terms of power density. In Thailand, the landscape is diverse such as plateau, plains, coastal plains, land, mountains, mountain ranges and hills. Generally, the wind speeds and directions change due to landscape. For this season, to study wind resource, investigation on topography is vital.

1. Introduction

Living with current's environmental problems, which includes some of the greatest threat to the earth such as global warming through emission of greenhouse gases and diminution of national forest, make the need it is a need of the hour to support the evolvement of the latest and renewable energy sources [1].

Continuing use of conventional power generation sources like water, biomass and petroleum would lead to an extremely negative effect on the environment. Usage of Biomass and petroleum leads to has strengthened the above-mentioned thread to earth [2]. Hydropower evokes energy crises due to constant drought resulting in drying of water reservoirs [3]. The increase in demand for cheap power caused by population growth, inflation and technological development is major

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problem in some countries like Kenya. In Kenya, to fulfil the energy deficit gap, the government has put in place rapidly the utilisation of diesel generators driven by government contracted Independent Power Producers (IPPs) [4]. This has increased the energy cost in return. By taking this problem on, Therefore, it is necessarily important to understand that how much a country's energy source affect the country's economy. Addressing this problem, it is mandatory to diversify other energy sources that are more reliable, durable and low-cost [5].

Several researchers are trying to study and utilize the wind energy in an efficient way, for instance, a study by Yazid *et al.,* which explain the parameters required for wind modelling. The wind flow condition depends on direction and the speed of upstream wind. It has a significant effect on the wind structure that occurs when the upstream wind creates momentum on the air. In addition, thermal atmospheric condition, which relate to the position of the sun in the sky and cloud cover, influences the location and direction of building surface area of building walls or surfaces heated by direct sunlight. According to this study, the temperature of difference in surface-to-air temperature is around noon, usually between 10 a.m. and 2 p.m. A tree planting pattern is that each tree has a different shape, size and properties. It depends on the type, age and environment. Tree size is characterized by height, trunk size and crown diameter [6].

Another Research in Malaysia showed the effect of vehicles movement on wind turbine speed was studied by Mazlan *et al.,* which chooses efficient wind turbines in low wind speed conditions. The efficiency of the wind turbine is sensitive to the speed of the vehicle and the angle of the guide vane. The movement of vehicles perturbs the flow distribution of wind speed. A row of wind guided vane panels was arranged in front of the blades of a wind turbine to prevent negative torque. Due to the speed of vehicles, the wind is scattered and uneven [7].

We are amidst several valuable renewable resources and out of them, Wind power is an expedient energy source that will be a reliable source going forward in the future. Wind power works by taking wind to create electricity [8]. Turbine which is a large-scale structure with many spinning blades, most of the time three, is used to convert air motion into electricity. It is referred to as a turbine is a large structure with several spinning blades usually three these blades are connected to an electromagnetic generator that generates electricity when the wind causes the blades to spin. This mechanism has gained tremendous significance in the energy sector globally. It is estimated that by the end of 2017, 539 GW of wind power capacity was installed around the world. The three countries with excessive installed capacity are China (188 GW), the United States, (89 GW) and Germany (56). 15–30% of the total electricity generation has been substituted by wind energy in most of the European countries. A large number of countries across the world are putting effort to enlarge wind power generation mechanization to fix the power capacity of electricity [9].

There is a classification of wind power mechanism based on capacity. Normally, the capacity of up to 1 kW-class is classified as “micro” and the capacity of 1–30 kW-class is classified as "small wind turbine”. Similarly, the capacity of 30–300 kW is taken as “medium". Small-scale wind power generators have achieved a substantial level of development in the global market, and there are roughly 250 small-scale wind power turbine manufacturers in 26 countries across the world [10]**.** Small scale wind power started to develop in the early 1980s. In 2015 the ratio of using small- scale wind power was doubled [8]**.** Indeed, a small wind energy system can also be an effective contributor to our energy needs. It is observed that this small-scale wind power has been used in small areas for the generation of electricity and privately in homes. The reason behind this is the lack of enough wind resources to manage the wind. However, the small – scale wind power is more beneficial for rural areas because it does not need transmission equipment, becoming more fit for a smart grid as a decentralized power supply system [11]**.** They are economical and create a low sound.

However, to develop wind power, there is a requirement of a lot of wind resources in terms of producing electricity. However differences in atmospheric pressure, wind speeds which varied based on geography, topography and season are the reason why in the tropical region like the south pacific, wind power generation is not easy because of not enough wind speed [8].

Wind energy is a renewable energy source that is being developed to take the place of the environmentally hazardous and unclean sources of electricity [12]. Wind power generation does not create direct co2 emission but it has other challenges to tackle and take its place in front line. Poor infrastructure, lack of technology, economic instability and lack of enough data in rural areas are some hurdles in way of creating wind power generation in some of the developing countries [13].

Wind turbine technology is used in Europe to generate electricity by large wind turbines with a capacity of 4-5 MW and is expected to be built to increase efficiency [14]. Wind turbine technology is based on wind turbine that is a device for converting the kinetic energy of the wind to mechanical energy. Then the mechanical energy is utilized. When the wind blows through the wind turbine, the turbine blade rotates and transfer kinetic energy to the turbine to generate the energy from this rotation [15].

Thailand is trying to increase dependency ratio to sustainable and renewable energy to compete the demand. The renewable energy installation capacity has doubled over the last decade. Renewable energy shares 15% of the overall consumed energy since 2018. Alternative Energy Development Plan-2036 by the government has set target to increase wind energy from 754 MW to 3,002 MW [16].

According to the Renewable Energy and Alternative Energy Development Plan (AEDP) 2018-2037. Thailand has set total wind power generation target of 3,000 MW until the end of the plan in 2037. Now, there is a total of 1,421 MW of electricity generated from wind power in the system (COD) [17] and Electricity Generating Authority of Thailand (EGAT) has a total power generation capacity of about 26 MW, with 2 major wind turbines, Phrom Thep Cape wind turbine in Phuket province with a capacity of 0.19235 MW and Lam Ta Khong wind turbine in Nakhon Ratchasima province with a capacity of 2.50 MW [18].

The topography of Thailand is classified into the following categories: mountains and plains of the North, Central Plains, North-eastern Plateaus, High Mountains of the West, Mountains and Coastal Plains of the East, Mountains, Plateaus, Coastal Plains and Islands of the South [19].

Since Thailand has a diversity of topography, hence it is an important selection criterion for defining the suitable areas which have a versatility of information and can be useful in the future. This paper provides information regarding the wind resource atlas of 15 areas from 6 regions state of Thailand.

2. Methodology

2.1 Wind Data Analysis

The wind data which includes wind speed, wind direction and temperature has been collected by installing anemometer at 15 stations in Thailand in 6 different regions of Thailand [20]. These 15 stations are categorized by their geographical location as shown in Figure1 [21].

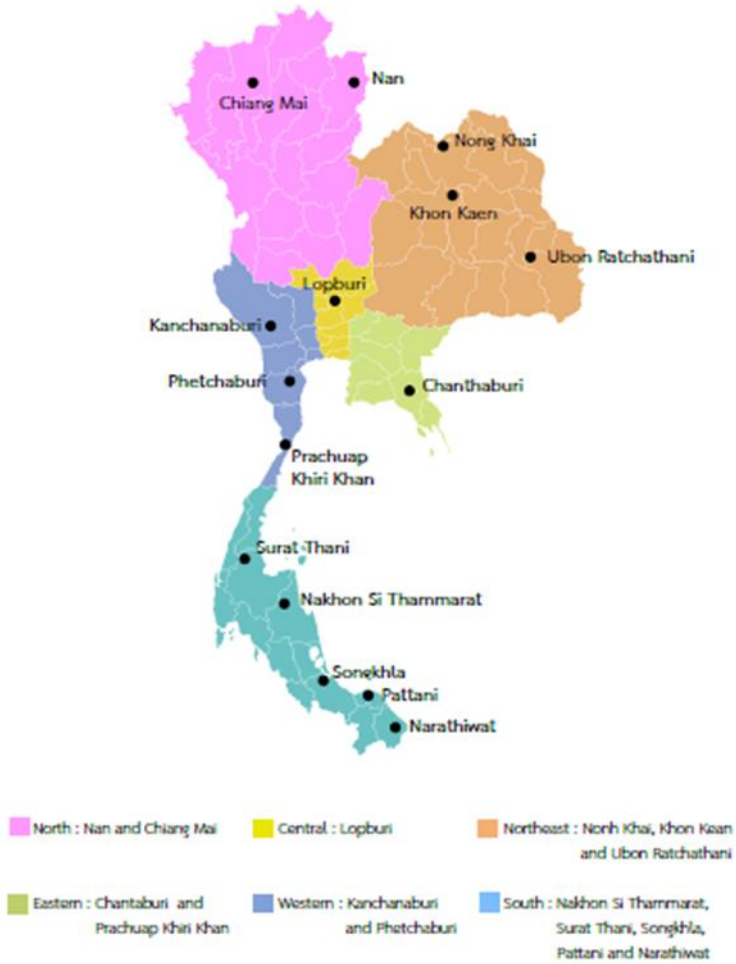


Fig. 1. Anemometer at 15 stations in Thailand in 6 different regions of Thailand, adapted by (source: https://khun240688.wordpress.com)

The data was collected at 5 different levels which are 10m, 15m, 20m, 25m, and 30m respectively for 16 November 2019 - 13 February 2020. The collected data is then processed by an industrial software Wind Analysis and Application Program (WAsP) developed by Riso National Laboratory, Denmark. This program facilitates to assess the wind situation and simulation of the potential wind energy. It also facilitates to calculate the mean wind speed by applying Weibull distribution function [22].

The results from the WAsP show the mean wind speed, main wind direction and wind power density of every station. Table1 shows mean speeds and Table2 shows power density of each station at 5 different levels. The reason of choosing 5 levels is to check the wind efficiency at different level.

Table 1
The mean wind speed for Height AGL 10,15,20,25,30 m

No	Wind statistics	Mean wind speed (m/s)				
		10 m.	15 m.	20 m.	25 m.	30 m.
1	Narathiwat	2.65	2.91	1.28	1.83	3.18
2	Songkhla	2.12	2.53	5.36	3.11	3.40
3	Nakhon Si Thammarat	4.24	4.38	4.30	4.91	4.97
4	Surat Thani	2.72	3.05	3.13	3.31	3.30
5	Prachuap Khiri Khan	1.81	2.11	2.29	2.64	2.82
6	Chanthaburi	2.22	3.61	2.66	3.53	4.96
7	Phetchaburi	1.59	2.11	2.07	2.53	1.99
8	Ubon Ratchathani	3.25	3.03	3.38	3.29	3.58
9	Khon Kaen	1.16	1.86	2.46	2.50	2.82
10	Lop Buri	1.86	2.02	3.89	2.23	2.47
11	Nong Khai	2.43	2.46	2.47	2.93	3.09
12	Pattani	2.19	2.20	2.48	2.96	3.20
13	Kanchanaburi	1.81	2.07	2.09	2.11	2.32
14	Nan	0.78	0.91	0.90	1.43	1.46
15	Chiang Mai	1.55	0.90	1.00	1.52	1.68

Table 2
The mean wind power density for Height AGL 10,15,20,25,30 m

No	Wind statistics	Power density (W/m^2)				
		10 m.	15 m.	20 m.	25 m.	30 m.
1	Narathiwat	23	25	2	5	25
2	Songkhla	11	15	126	24	29
3	Nakhon Si Thammarat	63	65	63	90	91
4	Surat Thani	19	22	24	32	31
5	Prachuap Khiri Khan	10	12	14	18	20
6	Chanthaburi	20	53	23	48	106
7	Phetchaburi	12	24	12	21	9
8	Ubon Ratchathani	48	44	60	56	62
9	Khon Kaen	3	6	10	11	16
10	Lop Buri	11	12	68	15	19
11	Nong Khai	28	30	32	53	46
12	Pattani	24	25	25	33	38
13	Kanchanaburi	18	21	20	20	21
14	Nan	0.78	3	2	8	8
15	Chiang Mai	12	2	2	3	6

2.2 Topographic Data Analysis

The terrain characteristics of the site for the wind energy highly influences the air flow and the power available in the wind. For this reason, study of the terrain and its effects on the wind are important factors. Landscape such as escarpments, hills and ridges affect the wind-speed. As a result, topographic data is necessary while performing wind resource assessment [11]. This paper includes spatial resolution of 100m and 150m of every station created in WAsP derived from Shuttle Radar Topography Mission (SRTM). Map extension is sized ranging from 20km*20km to 50km*50km depending on the landscape of the station. Table3-6 shows the elevations and surface map of each station.

Table 3
The map extension 20km*20 km (elevations and roughness map)

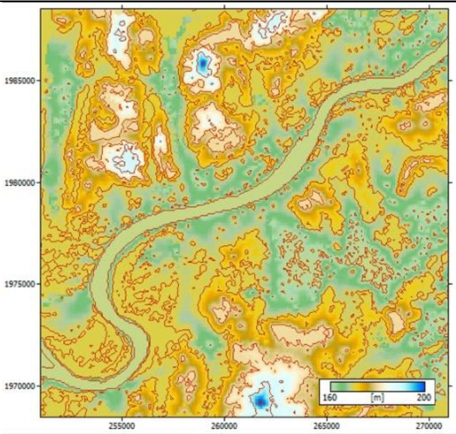
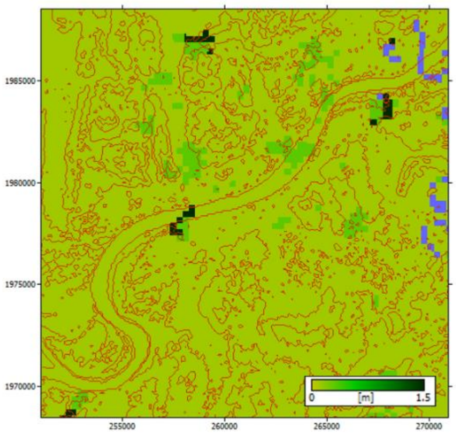
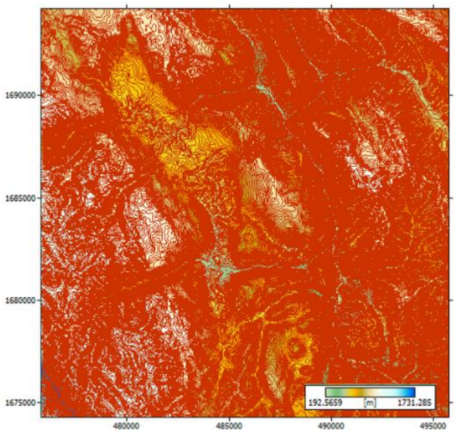
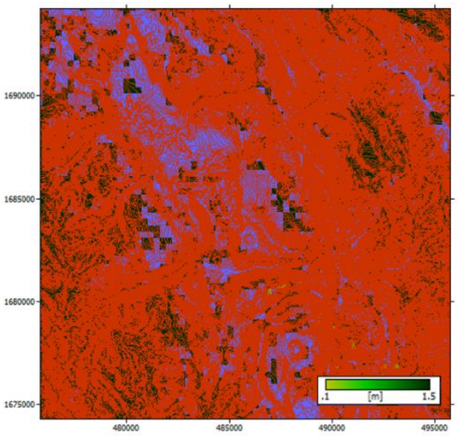
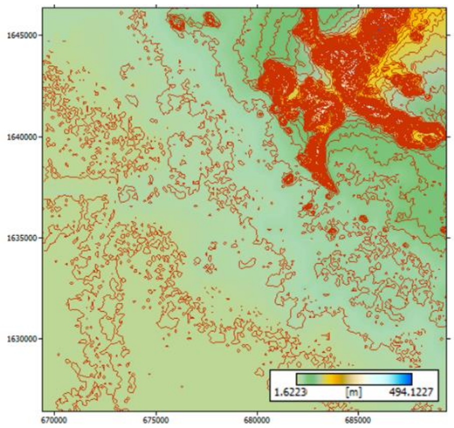
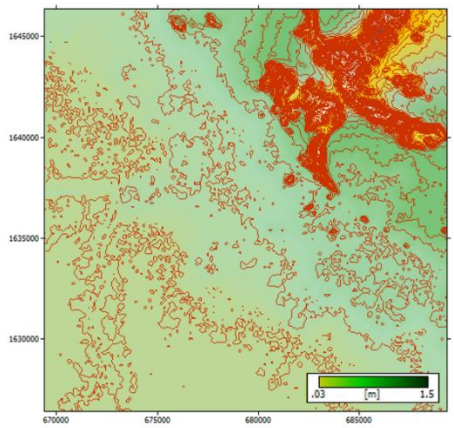
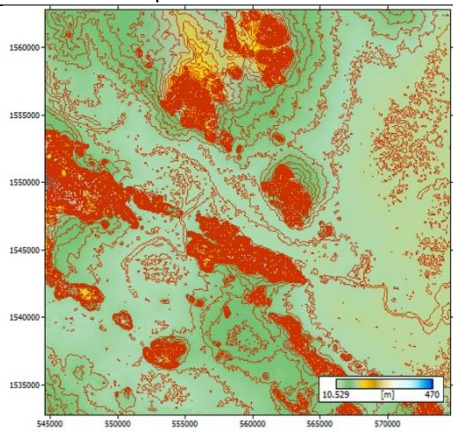
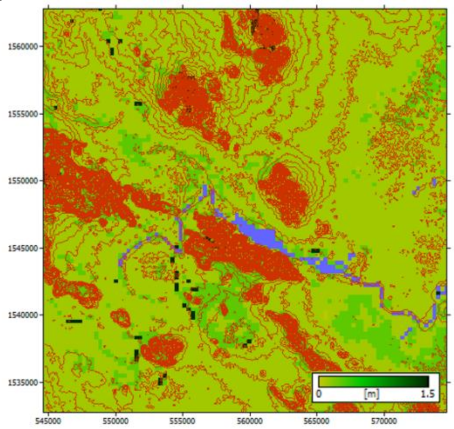
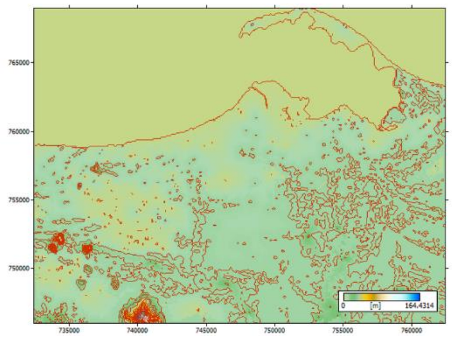
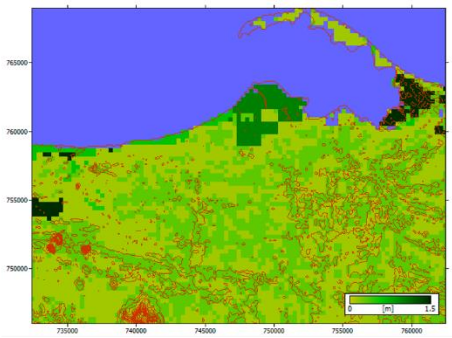
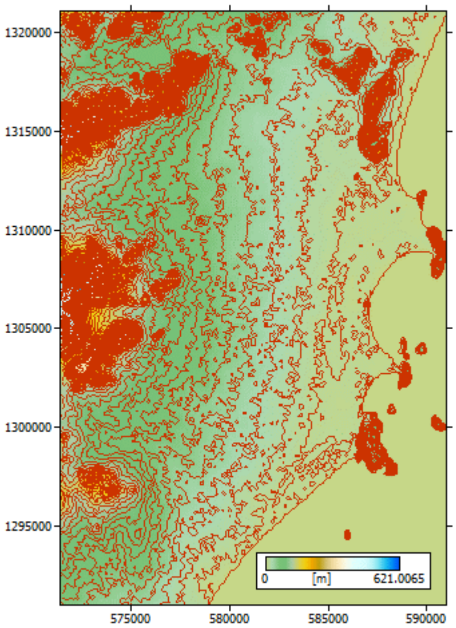
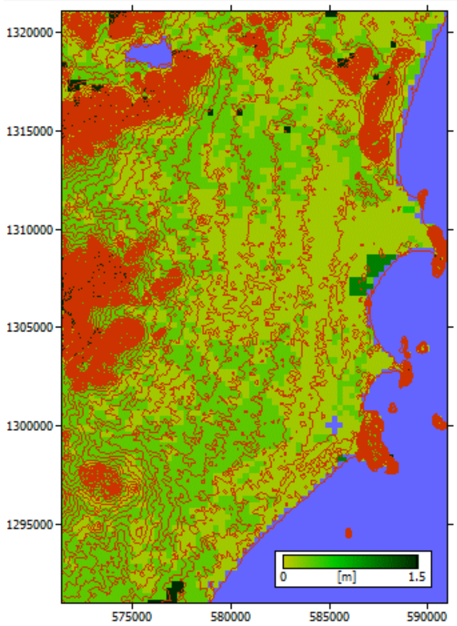
No.	Province	Elevations map	Roughness map
1	Nong Khai		
2	Ubon Ratchathani		
3	Lop Buri		

Table 4
The map extension 30km*30 km (elevations and roughness map)

NO.	Province	Elevations map	Roughness map
1	Kanchanaburi		
2	Pattani		
3	Prachuap Khiri Khan		

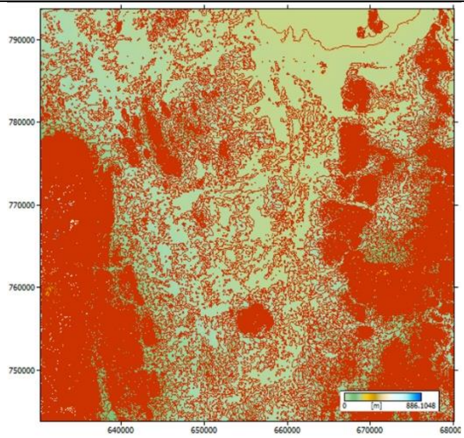
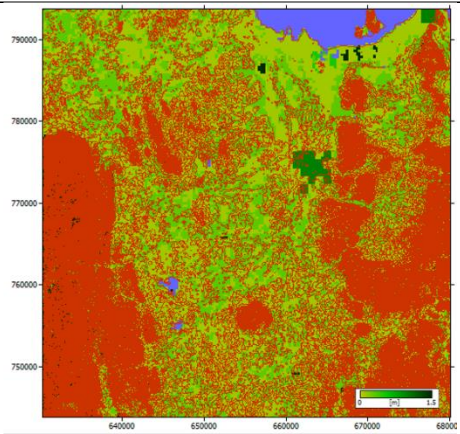
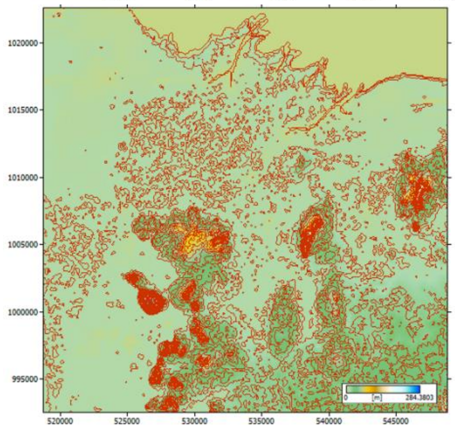
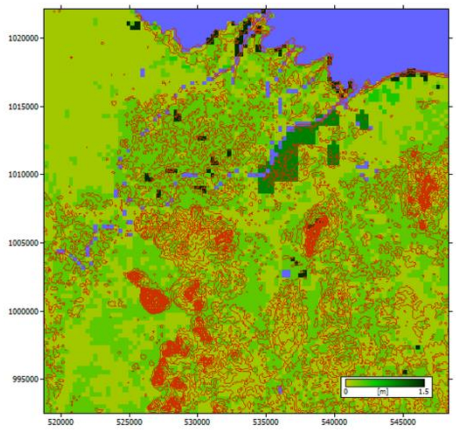
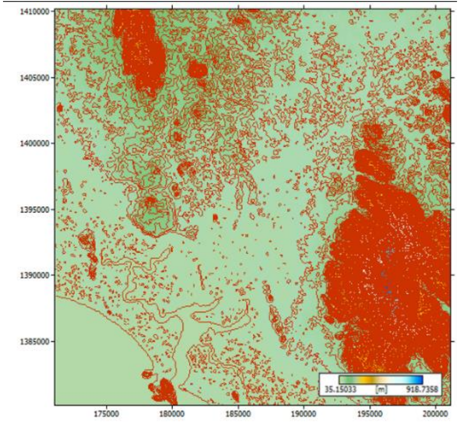
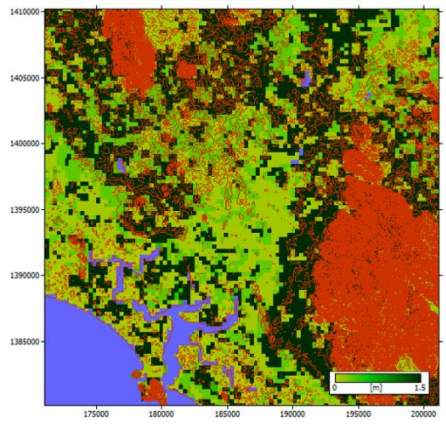
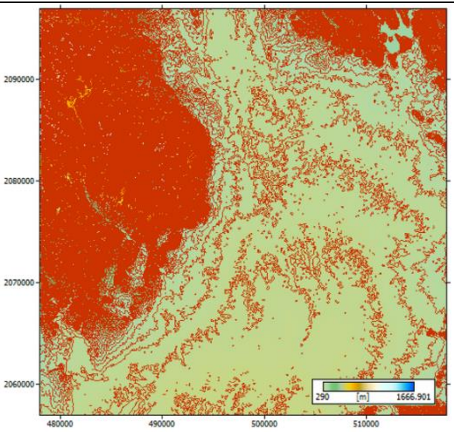
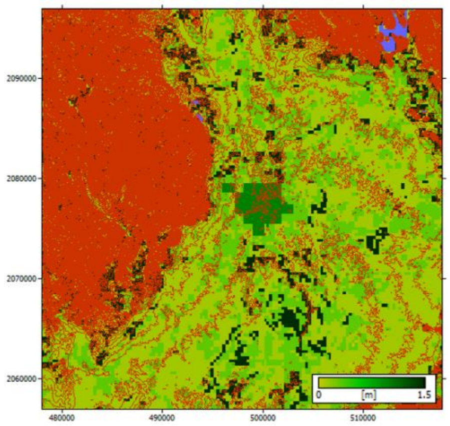
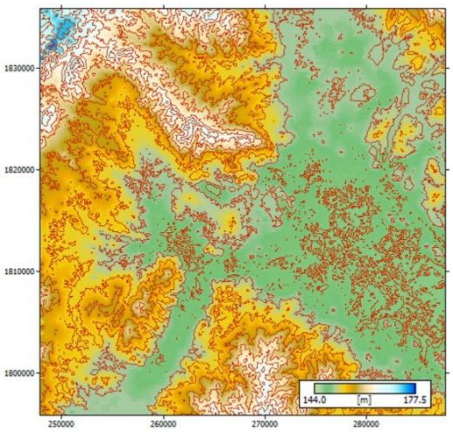
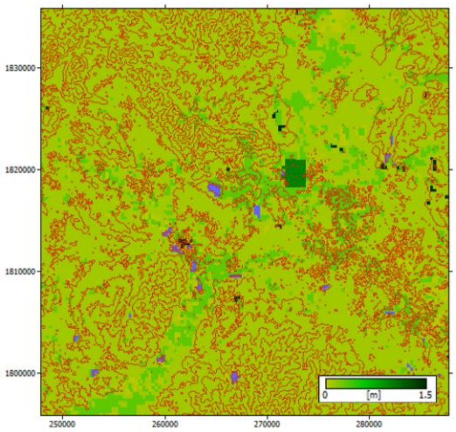
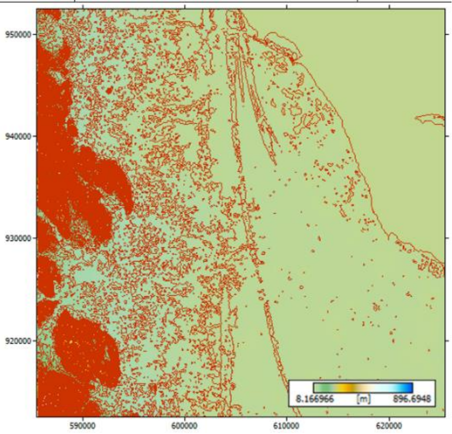
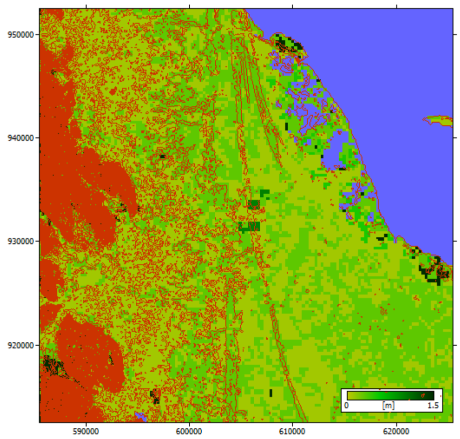
4	Songkhla		
5	Surat Thani		
6	Chanthaburi		

Table 5
The map extension 40km*40 km (elevations and roughness map)

NO.	Province	Elevations map	Roughness map
1	Chiang Mai		
2	Khon Kaen		
3	Nakhon Si Thammarat		

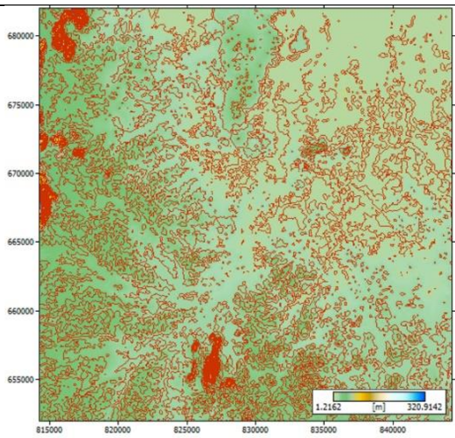
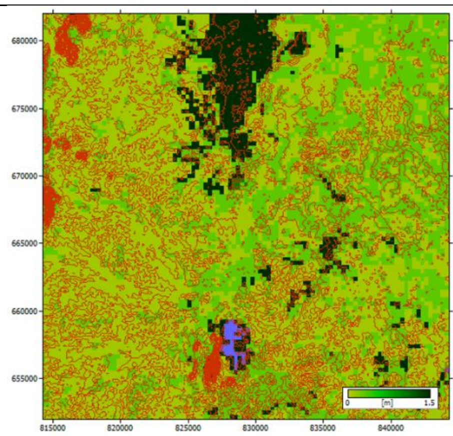
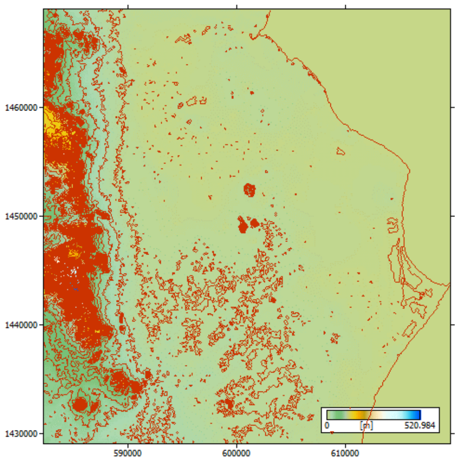
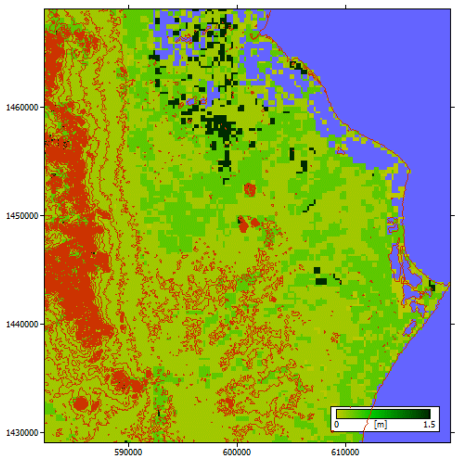
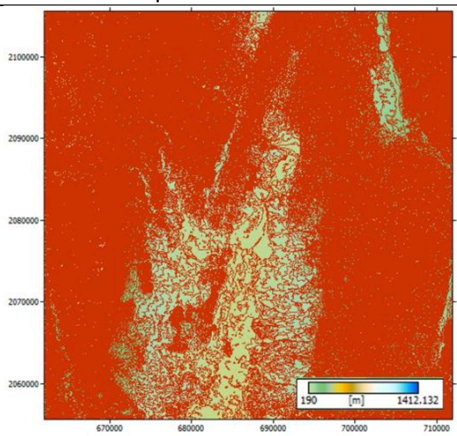
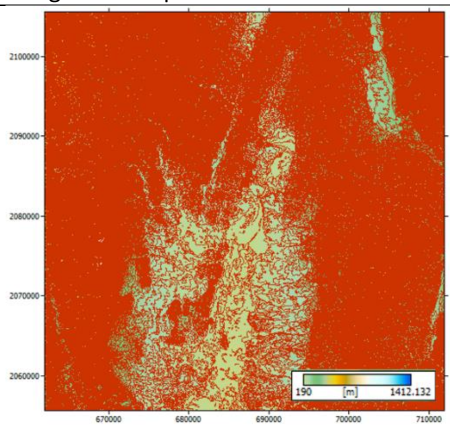
4	Narathiwat		
5	Phetchaburi		

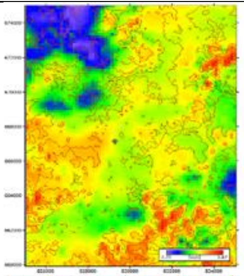
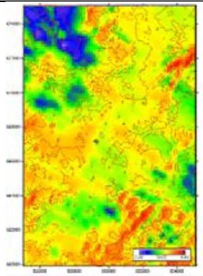
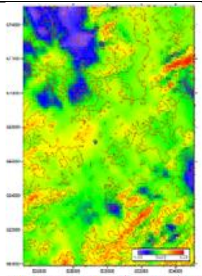
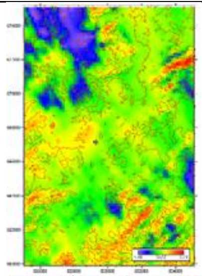
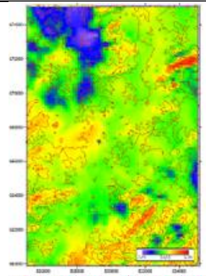
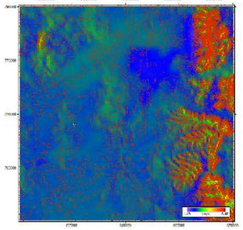
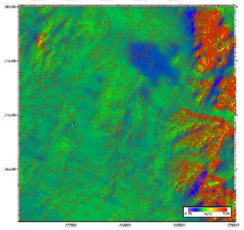
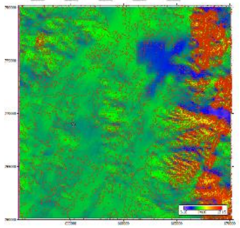
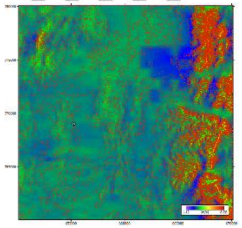
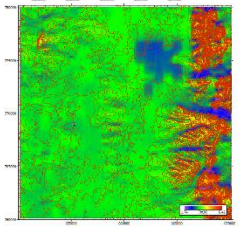
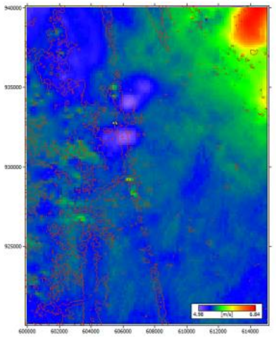
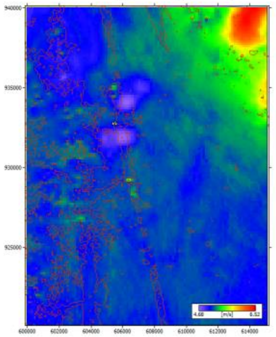
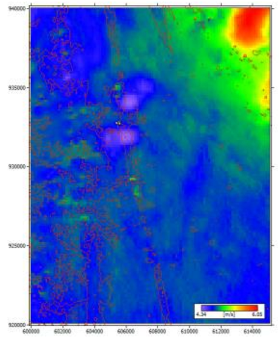
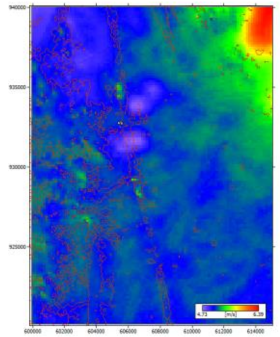
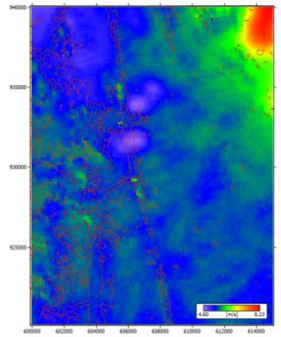
Table 6
Show map extension 50km*50 km (elevations and roughness map)

NO.	Province	Elevations map	Roughness map
1	Nan		

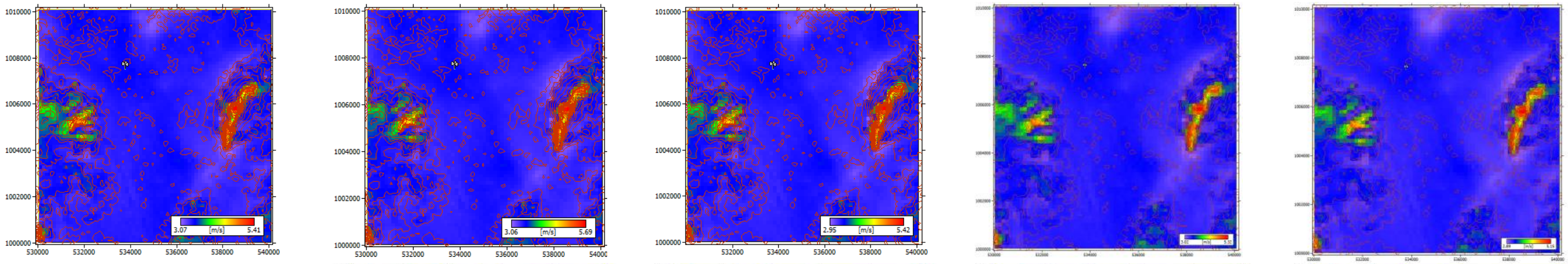
3. Results
3.1 Mean Wind Speed Map

The mean wind speed of 15 stations is calculated at 5 different levels which are 10m, 15m, 20m, 25m and 30m. Additionally, the mean wind speed data is merged with the map to create mean wind speed map of every station at different levels. It is observed by analysing the Table 7 that the highest mean wind speed is in Songkhla which ranges from 3.16-12.15 m/s and the lowest mean wind speed is in Narathiwat ranging from 1.13-1.72 m/s

Table 7
Wind speed map

Province	10	15	20	**25**	**30**
1. Narathiwat					
2. Songkhla					
3. Nakhon Si Thammarat					

4.Surat Thani



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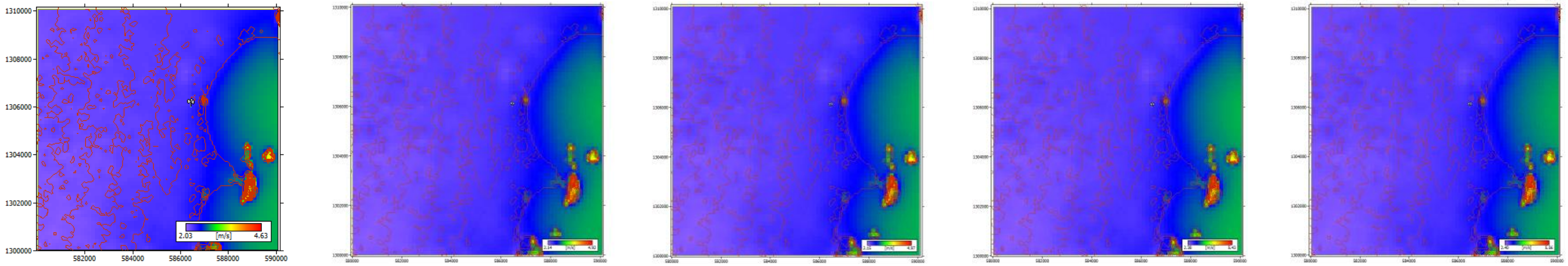

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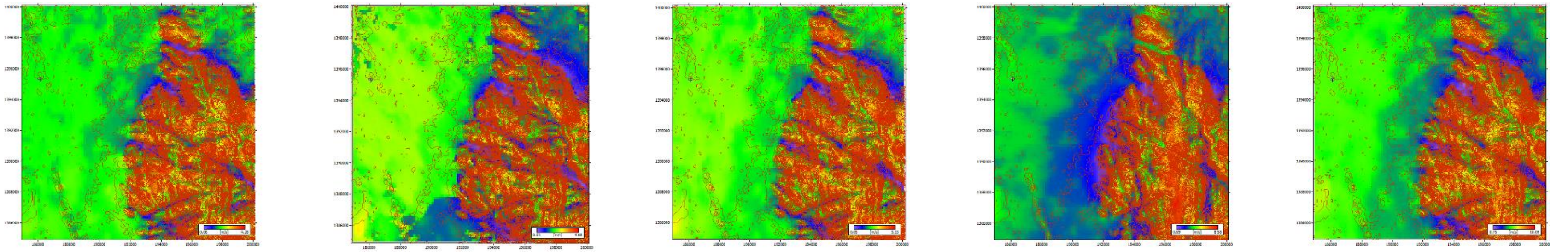
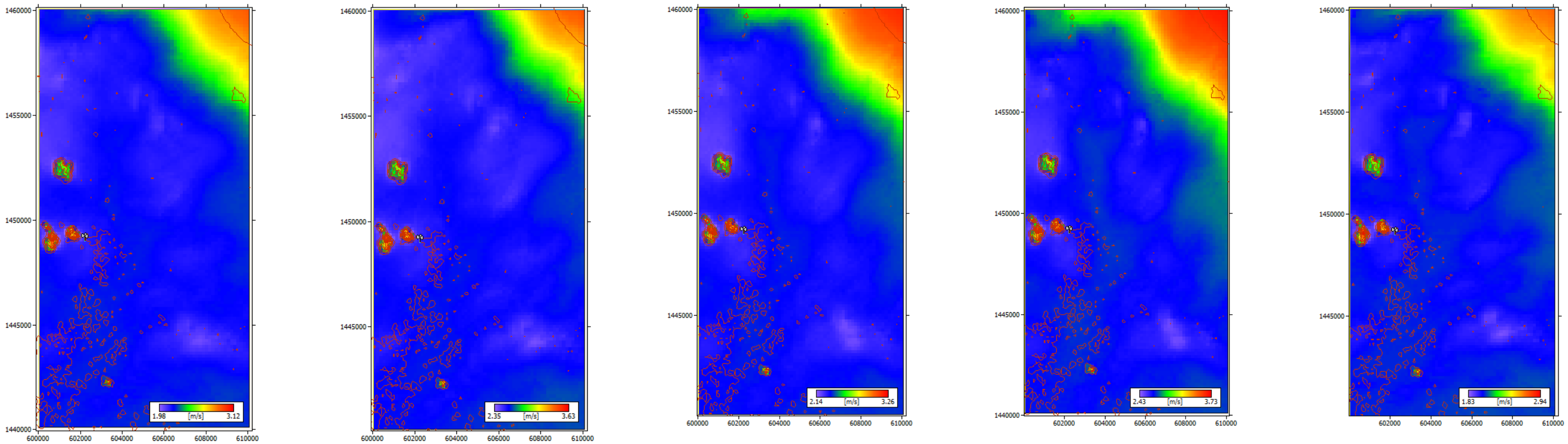
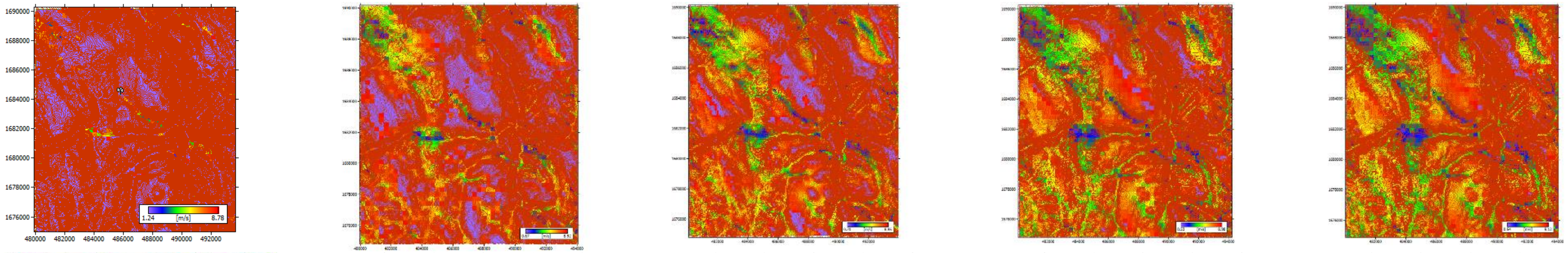


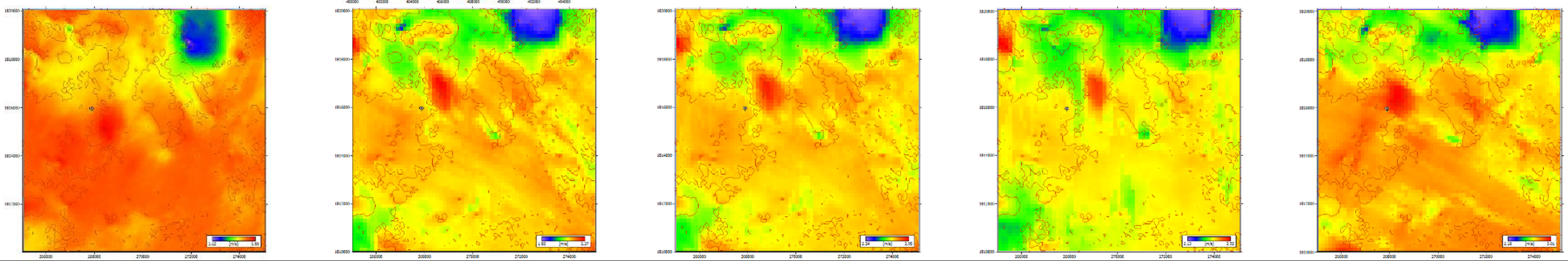
7. Phetchaburi



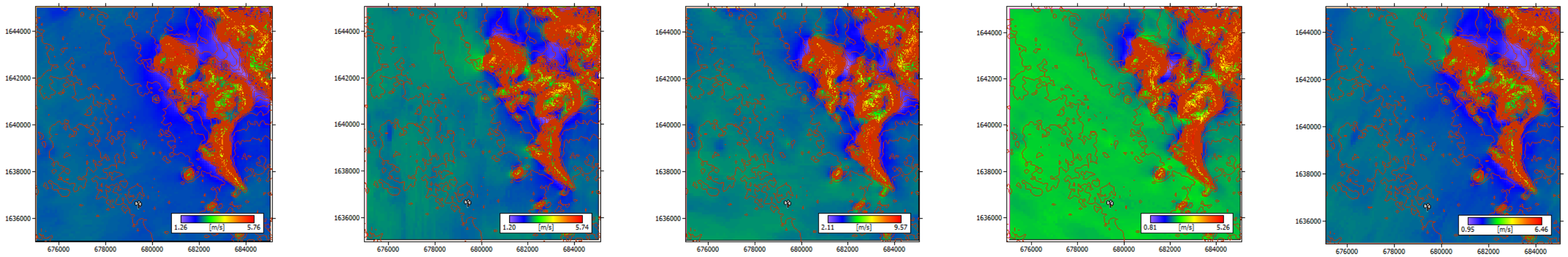
8. Ubon Ratchathani



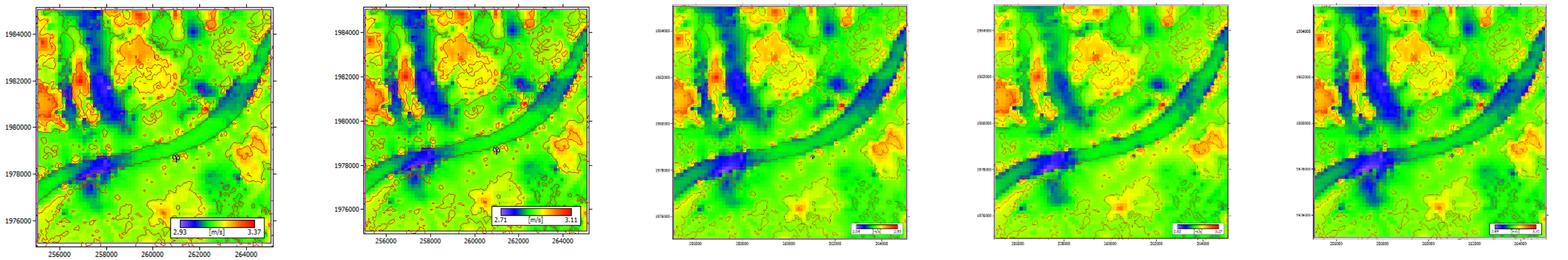
9. Khon Kaen



10.Lop Buri



11. Nong Khai



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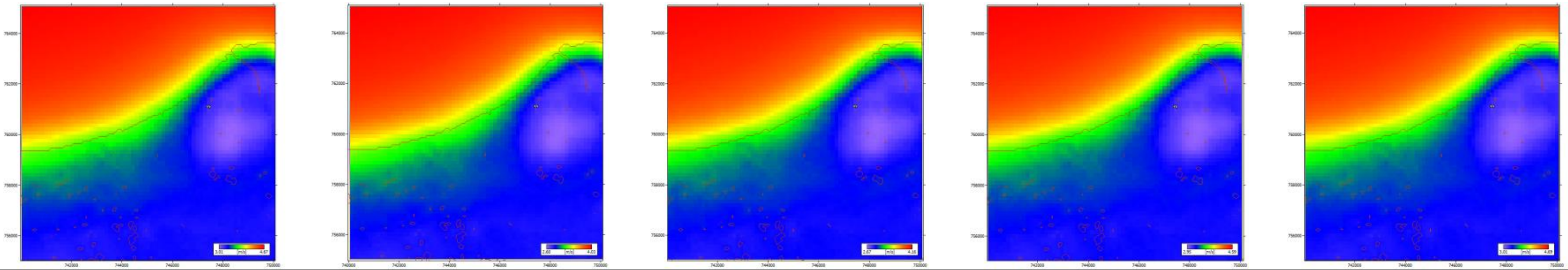

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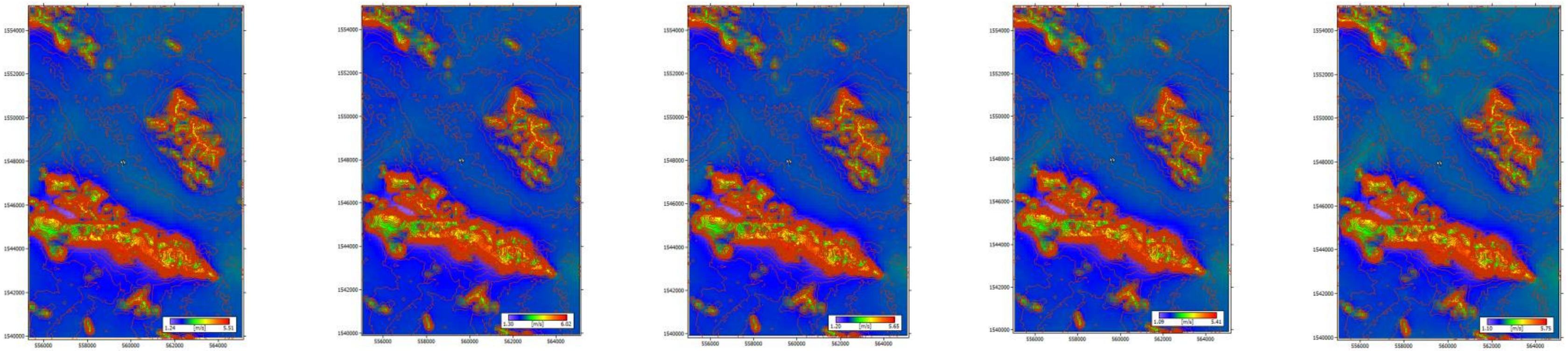

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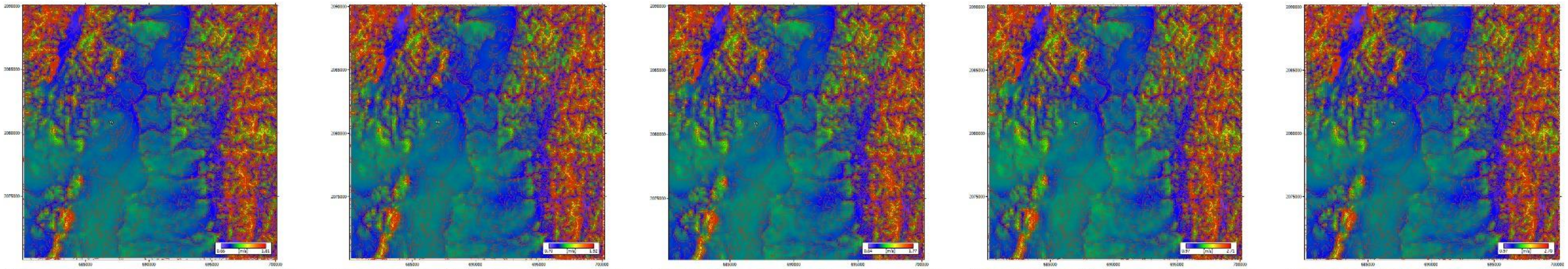
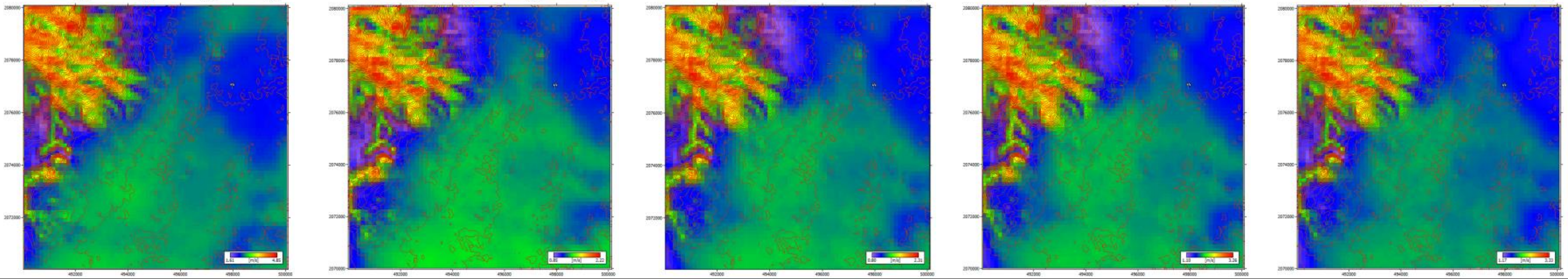


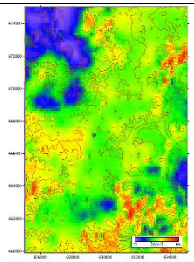
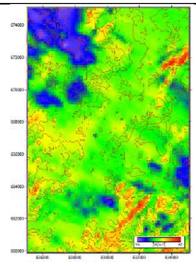
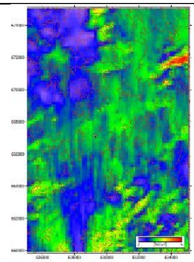
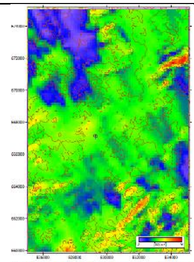
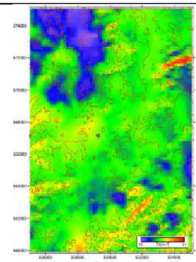
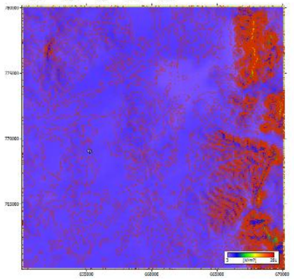
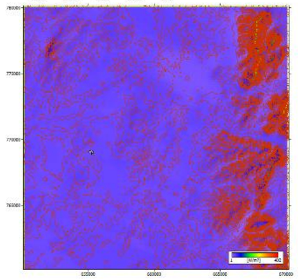
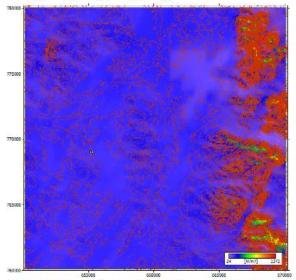
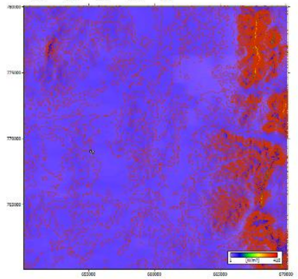
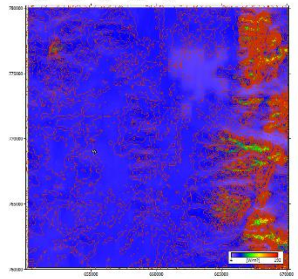
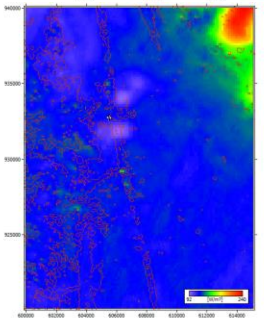
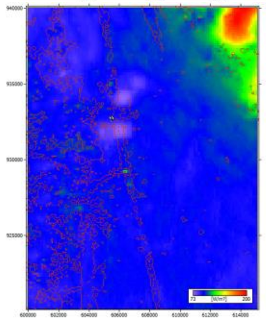
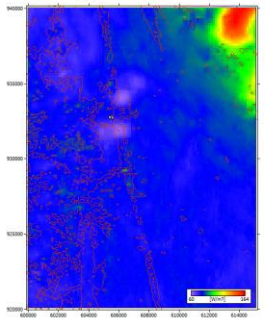
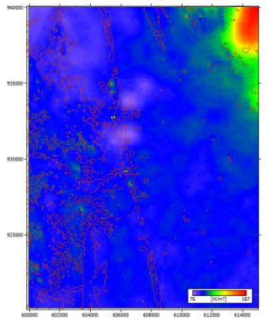
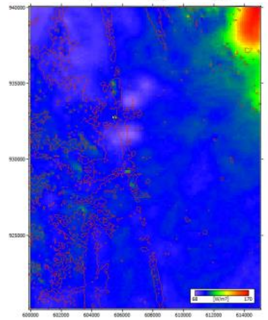
15. Chiang Mai



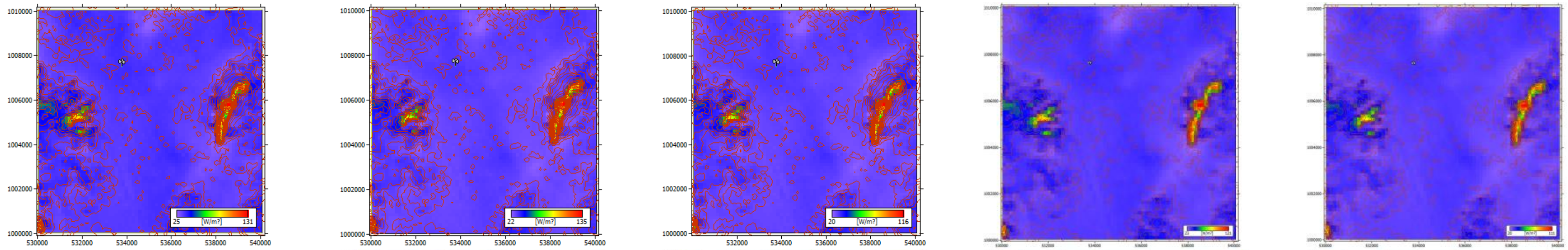
3.2 Mean Wind Power Density Map

Mean wind power density map is created by using the same map processed by WAsP and merged it with the calculated wind power density. Table 8 shows the mean wind power density map of every station at different levels. The highest wind power density is in Songkhla which ranges from 24-1372 W/m^2 and the lowest wind power density speed is in Narathiwat ranging from 2-5 W/m^2.

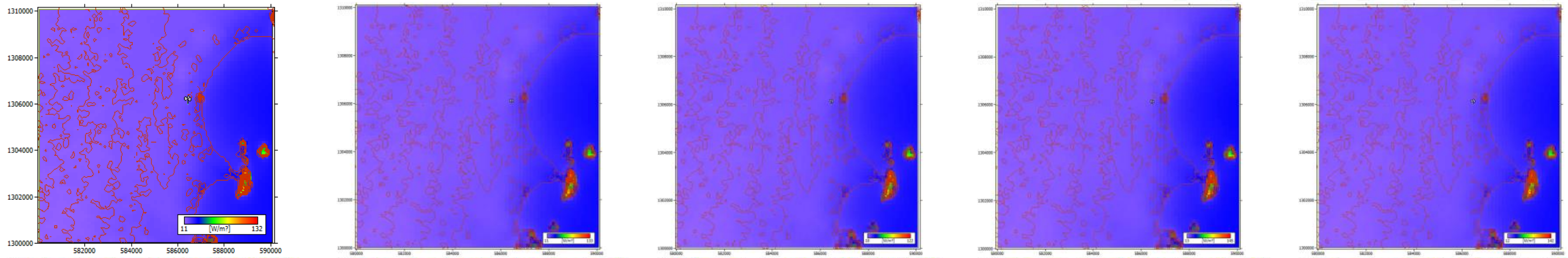
Table 7
Wind power density map

Province	10	15	20	**25**	**30**
1. Narathiwat					
2. Songkhla					
3. Nakhon Si Thammarat					

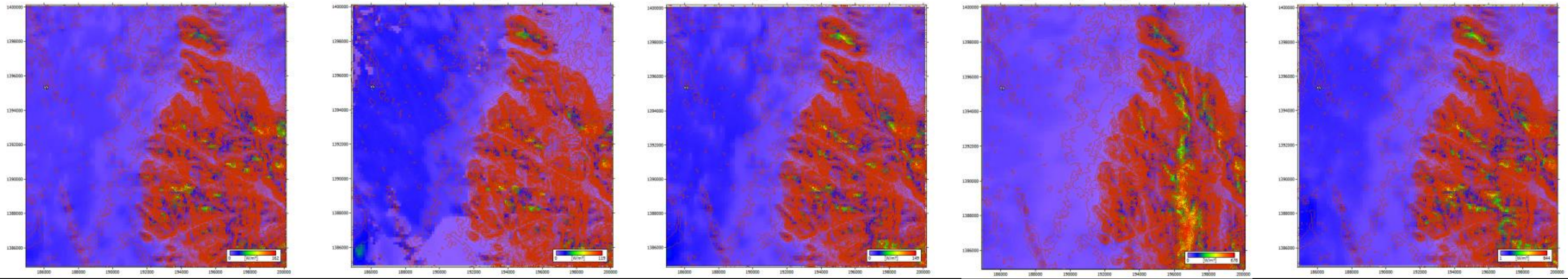
4.Surat Thani



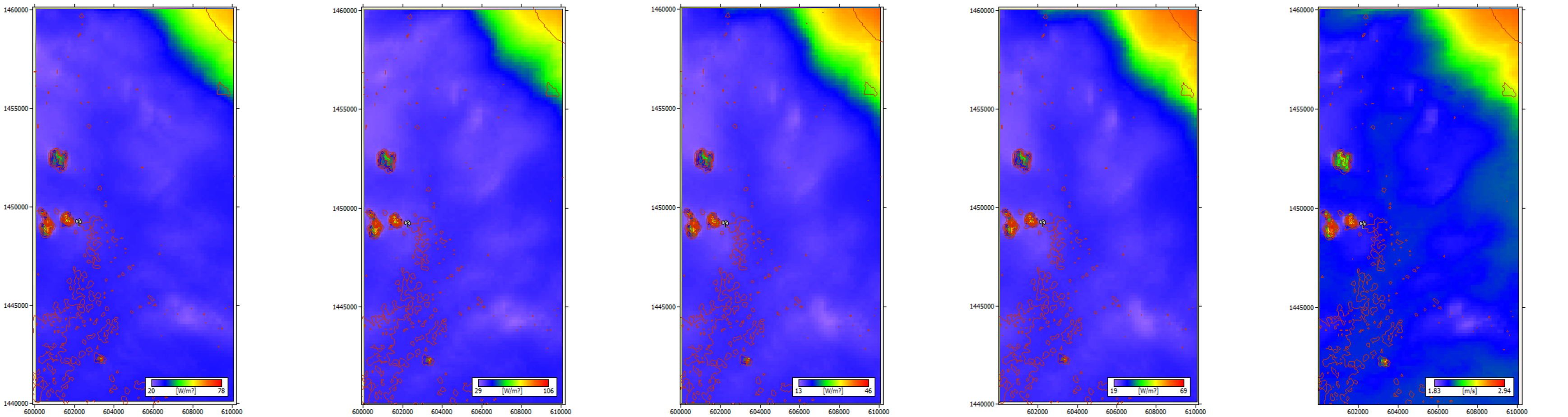
5. Prachuap Khiri Khan



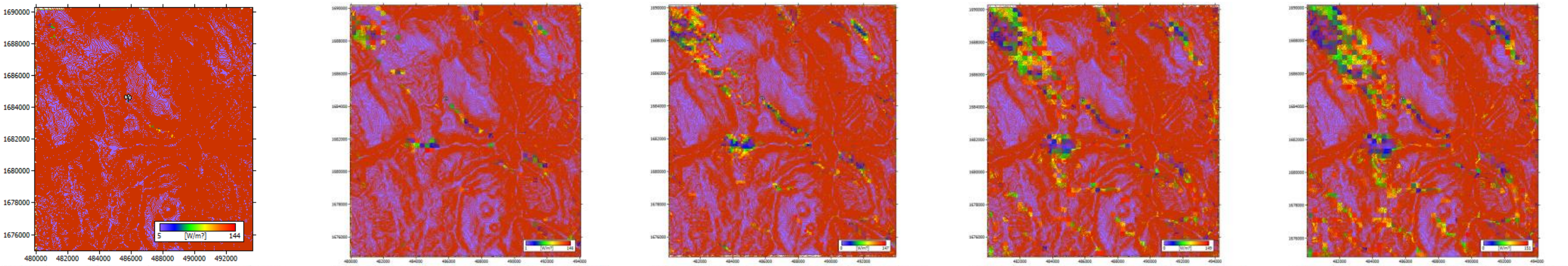
6. Chanthaburi



7. Phetchaburi



8. Ubon Ratchathani



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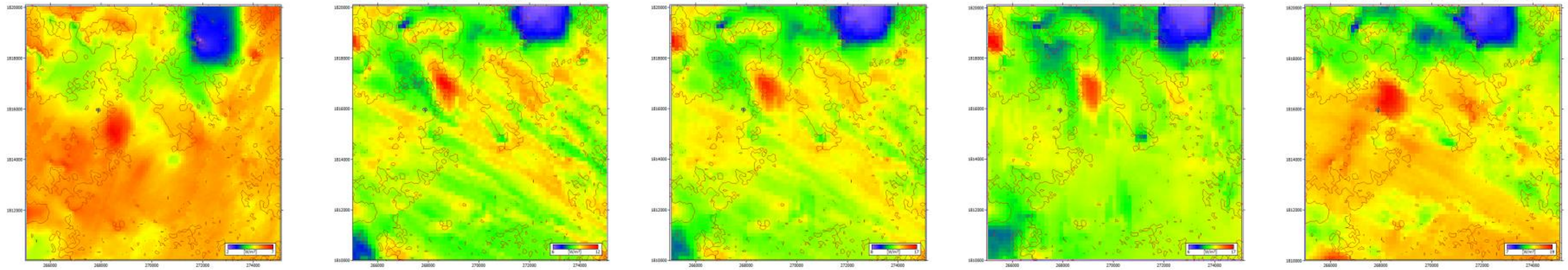

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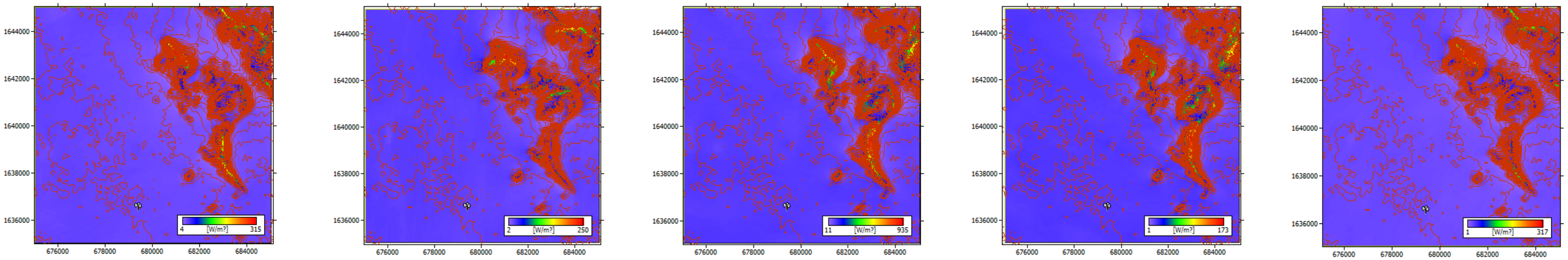

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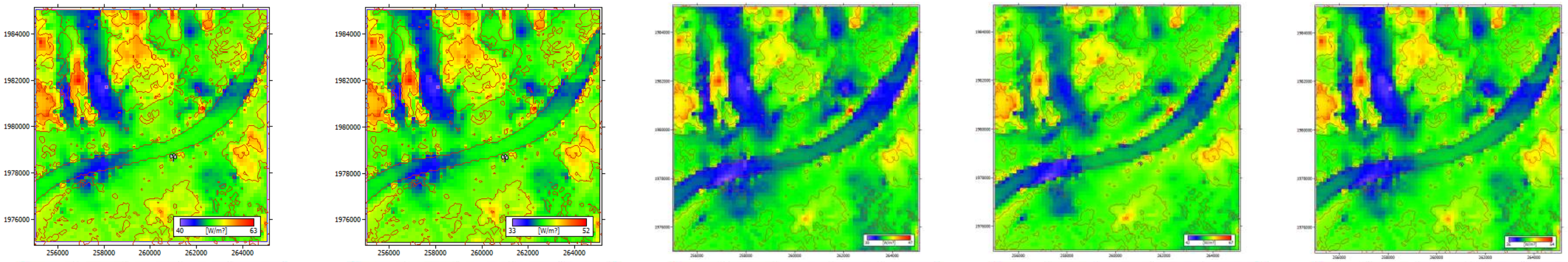

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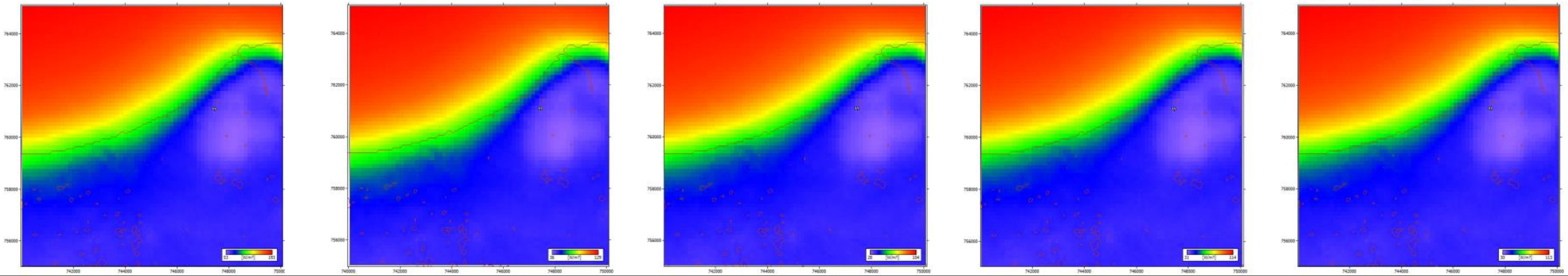
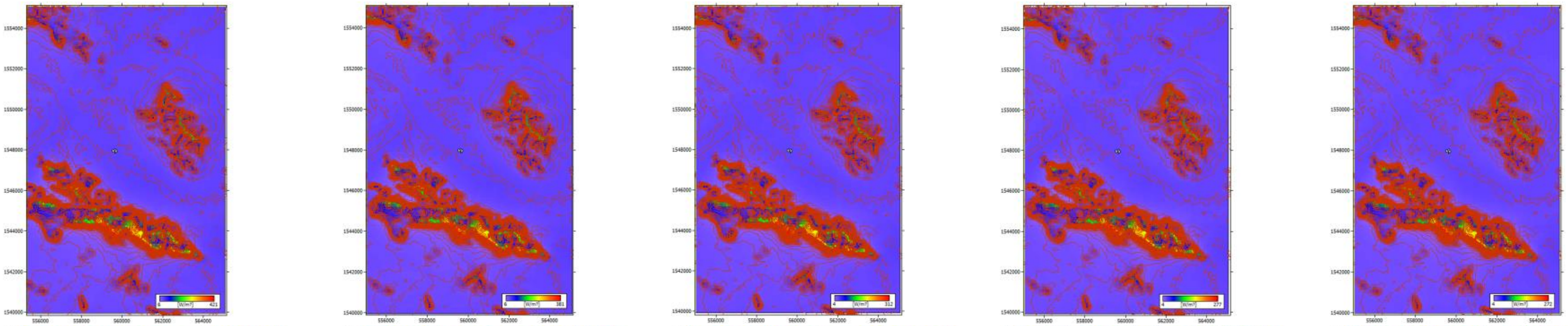
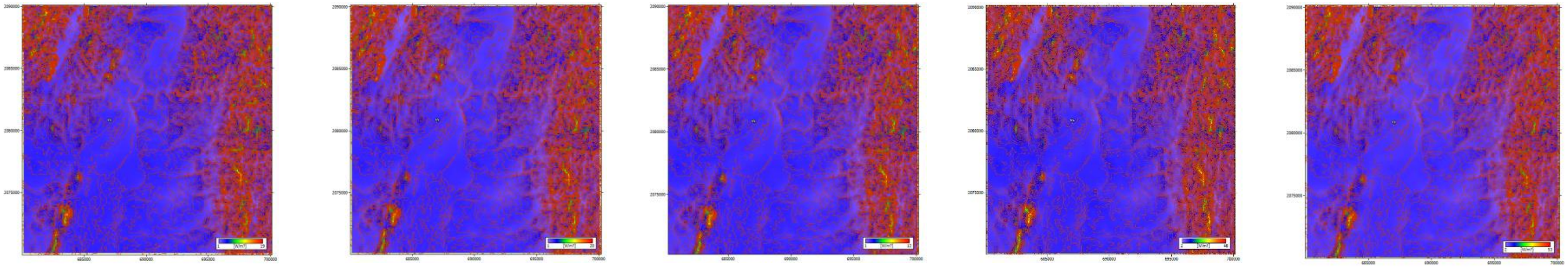


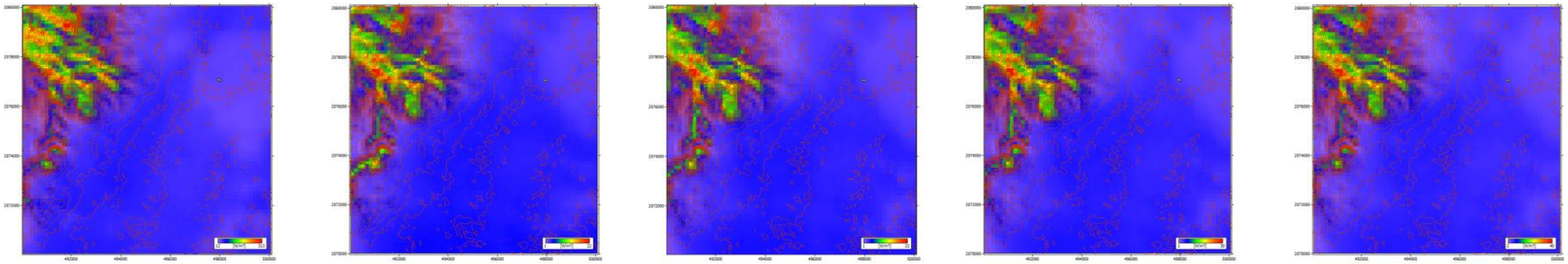
13. Kanchanaburi



14. Nan



15. Chiang Mai



4. Conclusions

The data of 15 different stations from Thailand were collected at 10m, 15m, 20m, 25m, and 30m height. Various heights affect the wind speed sensor and the direction of the wind. Furthermore, each height has different structures, trees or external factors. When the wind blows, various obstacles affect cause the change of wind speed. In addition, each survey area is different in terms of topography and climate, such as mountains, which are high and do not affect the wind. Moreover, in some areas there are different monthly monsoons. As a result, the wind speed in each area is different as well. The results showed that, at an altitude of 30 meters, there were less obstructions or relatively few wind obstructions. Thus, having a higher wind speed. Therefore, it is necessary to study the area covering various geographic and climatic conditions. To provide this information, the data was processed by WAsP software to generate the mean wind speed and power density of the wind. Furthermore, the topographical maps were also generated to produce the clear picture of the location and then merged with the wind data. The results showed that the highest mean wind speed station located in Songkhla, which ranged from 3.16 to 12.15m/s and lowest mean wind speed station situated in Narathiwat which was between 1.13 to 1.72m/s. Moreover, the power density in Songkhla station ranged from 24-1372W/m^2 and power density in Narathiwat station was from 2-5W/m^2.

Many factors, both natural and man-made, influence the wind speed in each place. Wind speeds were found to be substantially high at high-altitude. It was because of low shear friction from obstructions at high altitude. The wind direction and speed were also affected by pressure gradient which related to topography and weather. Increase in wind velocity increase the wind power density. Therefore, the suitable site for wind farms can be determined by wind speed at this location.

Acknowledgement
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