

Research on Wind Field Characteristics of High-Altitude Area in Tibet

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Abstract. Tibet is rich in clean energy such as solar energy, wind energy and water energy. But the region also has environment characteristics such as high altitude, low pressure and strong radiation, and it is very different from the wind field characteristics of transmission lines in low altitude area. In order to define the wind field characteristics along the transmission lines, this paper analyzes the meteorological modes of the two wind fields with densely-deployed transmission lines; verifies the mode analysis results based on the actually measured data of meteorological stations and gradient anemometer towers; and on the basis of ensuring the accuracy and reliability of mode analysis results, further analyzes the change law of wind speed and wind speed profile in recurrence interval of high-altitude area, and provides relevant design parameters for construction of transmission lines in this area.

Keywords: transmission lines, meteorological mode analysis, wind profile, and wind speed in recurrence interval.

1. Introduction

“Creating a new pattern of Eurasian regional economic integration” is part of the overall strategic objective of One Belt and One Road. The Qinghai-Tibet Plateau is located in the westernmost part of China and is the western fortress connecting South Asia, Central Asia and other countries and maintaining the security of China. As an important energy base in China, the Qinghai-Tibet Plateau also has great development potential in solar energy, wind energy, water energy and geothermal energy. Transmission lines are much more sensitive to environment especially extreme weather events [1]. The power grid disasters caused by meteorological factors [2] such as windage yaw flashover, pollution flashover, ice flashover, swing, lightning flashover, and collapsed tower and pole etc., which have a wider range of impacts and more serious consequences. Extreme meteorological factors such as icing, gale and thunder, have become the key factors affecting safety design, investment costs and operation benefits of projects.

As Tibet has a vast territory with a sparse population, meteorological workers have carried out more researches [3] and made achievements [4-6], but the wind field characteristics of many transmission lines are not clear compared with the extensive coverage of transmission lines. Therefore, it is necessary to carry out a series of engineering meteorological researches on the construction of



transmission lines in the high-altitude area of Tibet. Among them, in view of the strong wind area, the researches on wind field characteristics and wind load characteristics have been conducted through the analysis of meteorological mode and the measured data validation, which provides the basic data and theoretical basis for the design load of transmission lines in the high-altitude strong wind area of Tibet.

2. Analysis of Wind Field Mode in High-Altitude Region of Tibet

2.1. Selection of Simulated Regions

According to the needs of operation and construction of transmission lines, the mode analysis is carried out in Naqu (Region I) and Dege (Region II) where the selected lines are relatively concentrated. In order to understand the climate characteristics of the two simulated regions and surrounding areas, the surveyed area will be expanded to a wider range of the two simulated regions (the area in the big black box in the picture is divided according to climatic zoning and limited in the region with climate characteristics similar to areas in Tibet as far as possible). It is used to analyze the climate characteristics of the simulated region and the surrounding area as well as the change rule of meteorological elements. As can be seen from the Figure, there are 55 meteorological stations in the whole surveyed area. Among them, there are 11 meteorological stations in Region I, 5 meteorological stations in Region II, and 39 meteorological stations in surrounding areas of the simulated region. There are 6 anemometer towers in which 2 are located within Region I, 2 are located in the northeast outside Region I, and the remaining 2 are located within Region II.

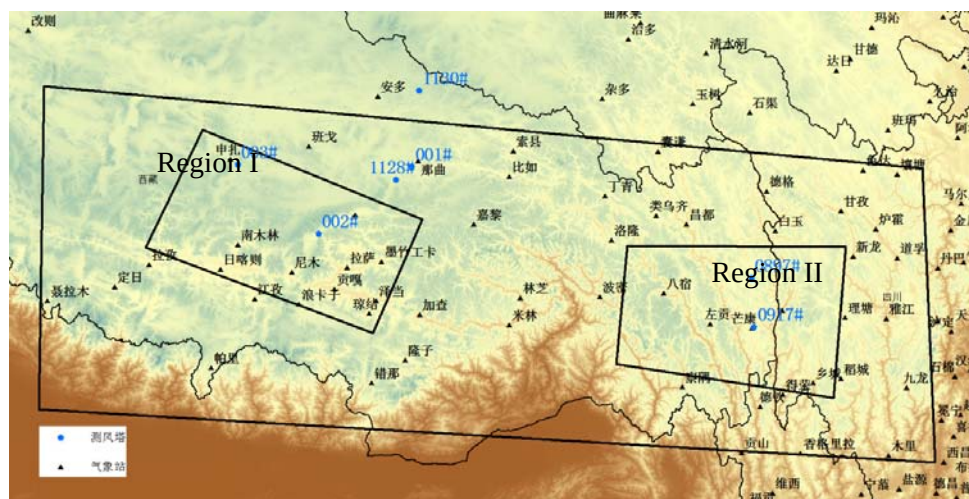


Figure 1. Location Distribution Map of Meteorological Stations and Anemometer Towers in Research Area and Nearby Areas

(Black Triangle: Meteorological Station; Blue Dot: Anemometer Tower)

2.2. Selection of Meteorological Data

For the scale meteorological mode during operation, the initial and boundary conditions need to be modified by meteorological observation data to obtain more accurate simulation results. The present report adopts the observation data from the National Meteorological Station, which has been compiled by the National Meteorological Information Center from 2016 to 2017. The distribution of meteorological stations is shown in Figure 2. The observation data of ground meteorological station includes temperature, dew point temperature, wind speed, wind direction, air pressure and precipitation.

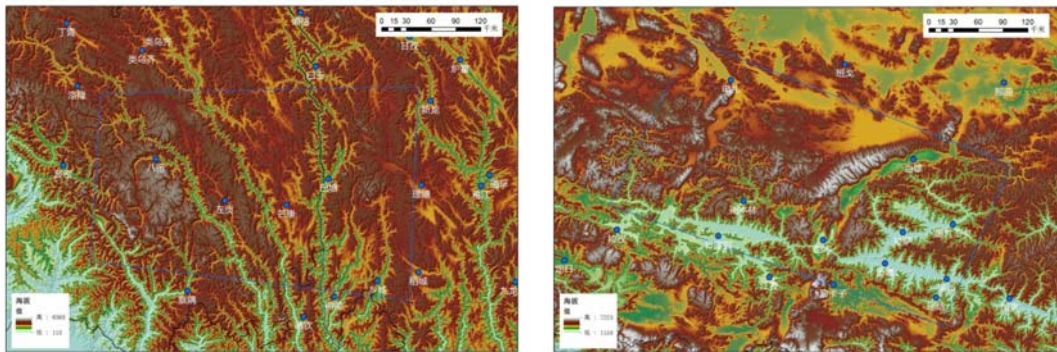
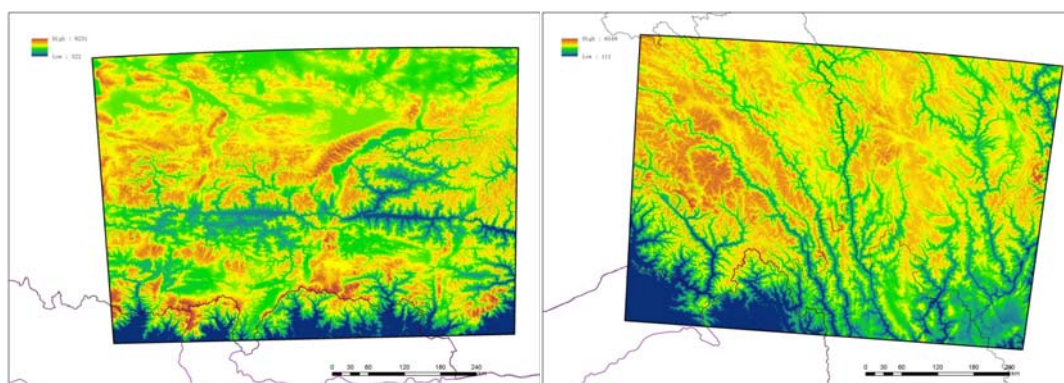


Figure 2. Schematic Diagram of Locations of Meteorological Stations

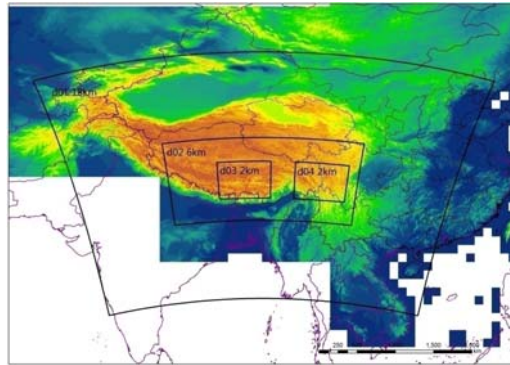
2.3. Modal Analysis Setting

There are two simulated regions, one in Naqu Region and the other in Qamdo-Dege Region. The WRF mode adopts 3 resets and the horizontal resolution is 18km, 6km and 2km respectively. As the simulation coverage is too large, the third reset is divided into two regions for concurrent simulation. The horizontal grid points are 541×532 and the vertical layers are 37. The initial and boundary conditions of the modal adopts EC horizontal resolution of $0.25^\circ \times 0.25^\circ$ of reanalysis data. Figure 3.3-1 shows the simulated regions and terrain information with horizontal resolution of 2km. The Figure shows that the terrain in the simulated range is more complex. The simulated region of Naqu (d03) is located in southern Tibet and the altitude is above 4000m in plateau. The southern side is located on the edge of Qinghai-Tibet Plateau where the altitude drops rapidly and the altitude difference is over 2000m. The simulated region of Qamdo-Dege (d04) is located in southeastern Tibet where borders Sichuan Province and Yunnan Province. The altitude changes are very high, which is higher in north and lower in south, and the altitude difference is over 2000m. Previous studies have pointed out that [7-10], the MYNN scheme could not only output the higher-order variable information, but also could be used to simulate the near-stratum wind field characteristics under complex terrain conditions. Therefore, the paper finally selects the MYNN scheme as the near-stratum and boundary layer scheme. In order to correct the simulation results by using the data of site anemometer tower, the simulation time was from May 1, 2016 to April 30, 2017. The modal running took each day as a calculating example. From 12:00 of the previous day in universal time, totally 36 hours were simulated. Only the 00:00-23:00 results in Beijing time simulated at that day were adopted. The mode output simulation results had a horizontal resolution of 2km and the time resolution was 1 hour.



(a) Schematic Diagram of Altitude in Simulated Naqu Region

(b) Schematic Diagram of Altitude in Simulated Qamdo-Dege Region



(c) Schematic Diagram of Altitude in Simulated Region

Figure 3. Schematic Diagram of Terrain Altitude within Simulated Range (Unit: m)

3. Analysis Result Check of Meteorological Mode

The meso-scale meteorological mode is used to simulate and obtain the simulation results with horizontal resolution of $2\text{km} \times 2\text{km}$ in the simulated Naqu Region and Qamdo-Dege Region. In order to improve the mode simulation ability of normal meteorological elements such as wind speed, wind direction, temperature and air pressure, the actually measured data from meteorological stations and anemometer towers within the simulation range are used to check and analyze the simulation results.

3.1. Analysis Result Check Based on Observation Data from Meteorological Station

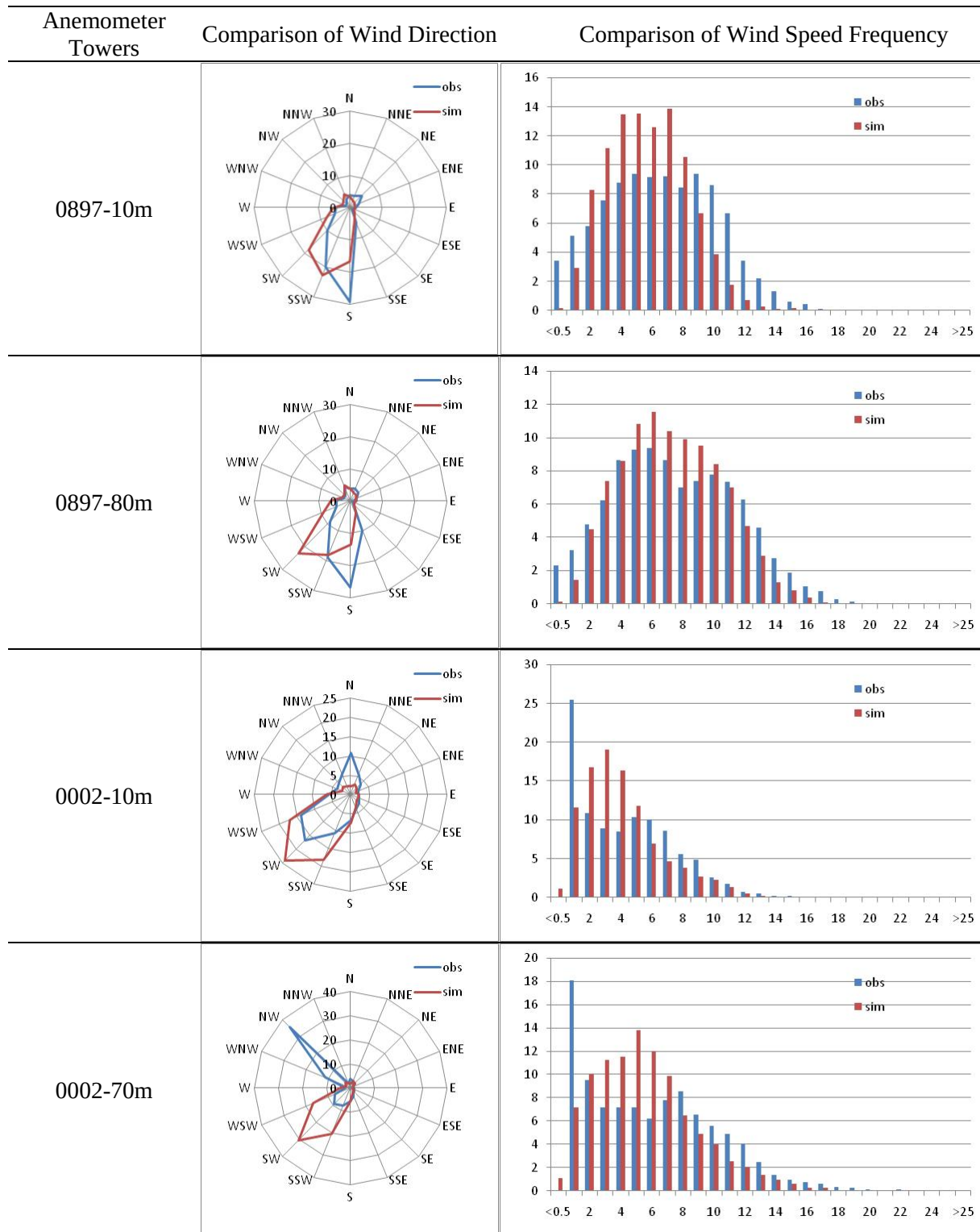
Table 1 shows the check comparison table of the simulation results from the meteorological stations and shows the check comparison results of the simulation results from the 26 meteorological stations in the simulated regions. The relative error of average wind speed is 19.45%, the absolute error of average wind speed is 0.48ms^{-1} , the average deviation of wind direction is 47.78° , the absolute error of average temperature is -2.03°C , and the absolute error of average air pressure is -14.94hPa . The average values of check indexes adopt the average absolute value of indexes from all the compared meteorological stations. Based on these average check indexes, this mode can well simulate the basic meteorological elements in the simulated Naqu and Qamdo-Dege Regions of Tibet.

Table 1. Check Comparison Table of Simulation Results from Meteorological Stations

	Relative Error of Average Wind Speed (%)	Absolute Error of Average Wind Speed (ms^{-1})	Average Deviation of Wind Direction ($^{\circ}$)	Absolute Error of Temperature ($^{\circ}\text{C}$)	Absolute Error of Air Pressure (hpa)
Bange	10.96	0.43	37.14	-1.67	-5.06
Naqu	38.91	0.93	46.61	-1.37	-2.30
Shenzha	30.72	1.16	46.90	-0.97	-0.48
Damxung	33.81	0.83	49.79	-0.95	-2.16
Lhatse	20.19	0.53	48.47	-2.47	-2.36
Shigatse	20.88	0.41	48.07	-1.57	-0.01
Nimu	27.98	0.54	50.55	-1.56	-4.49
Lhasa	19.84	0.38	51.62	-1.93	-0.45
Mozhugongka	1.79	0.05	53.98	-1.20	-1.34
Qiongjie	12.71	0.38	50.51	-1.40	-4.97
Tsetang	34.26	0.83	50.15	-0.11	-2.01
Dingri	24.01	0.67	42.69	-3.00	-8.43
Jiangzi	15.52	0.36	51.94	-1.91	-9.23
Cuona	-1.29	-0.05	38.66	-0.80	-4.81
Longzi	33.09	0.79	48.16	-2.95	-27.42
Pali	-10.63	-0.41	46.49	-0.96	-9.32
Xinlong	32.66	0.68	46.08	-3.47	-37.20
Dunbar	41.22	1.16	45.77	-2.80	-34.95
Yajiang	36.34	0.71	51.40	-3.31	-41.55
Kangting	6.43	0.20	42.72	-3.39	-56.87
Chayu	9.06	0.14	49.72	-5.83	-62.82
Muli	20.93	0.45	53.48	-3.70	-30.82
Jiulong	-6.00	-0.17	54.59	-3.19	-30.88
Shangri-La	8.71	0.25	51.49	-0.36	-1.31
Yanyuan	35.38	0.88	46.07	-0.73	2.91
Ninglang	8.10	0.26	39.23	-1.31	-10.22
Average	19.45	0.48	47.78	-2.03	-14.94

3.2. Check of Analysis Results Based on Observation Data from Anemometer Tower

Table 2 is the comparison table of simulation results of wind direction frequency and wind speed frequency from observation anemometer towers of 4-base gradient within the simulated regions. It can be seen that the wind direction frequency and wind speed frequency in the simulated anemometer towers are almost consistent with the actually measured results. The visible mode can well simulate the wind field characteristics in the simulated Naqu and Qamdo-Dege Regions of Tibet.

Table 2. Comparison Table of Simulation Results of Wind Direction Frequency and Wind Speed Frequency in Anemometer Towers

4. Analysis of Wind Field Characteristics of Transmission Lines within Simulated Regions

When transmission lines are designed, the average wind speed at height of 10m is very important to calculate wind load of transmission lines. It is necessary to focus on the characteristic parameters of the wind field. Moreover, the transmission line tower is a high-rise structure and the wind speed at different altitudes greatly impacts the wind load of tower body, which also needs focusing. Based on the mode analysis results, this paper analyzes the parameters of these two wind fields.

4.1. Analysis of Wind Speed of 50/100-Year Recurrence Interval

Within the simulated regions, the stations with long wind speed recording are only located in Shigatse, Lhasa, Tsetang and Batang. The first three are located in the simulated Region I meanwhile the last one is located in the simulated Region II. The annual maximum wind speed decreases year by year in the stations of Bange, Tsetang, and Longzi within the simulated Region I. The maximum wind speed is stable in the stations of Shigatse and Lhasa. However, the Lhasa station is located in the urban area and the wind speed is affected by the surrounding buildings; meanwhile the Shigatse station is located in the outskirts. The predominant wind direction of Shigatse station is WSW and SE meanwhile the predominant wind direction of Lhasa station is W and E-ESE. In addition to reflecting the influence of systematic wind, the wind direction in Shigatse station also reflects the influence of local topography. Therefore, Shigatse station is selected as the reference station within the simulated Region I. The annual maximum wind speed decreases year by year in the stations of Qamdo, Nyingchi, Deqin, Litang, and Xinlong within the simulated Region II. Only the maximum wind speed in Batang station is relatively stable. Therefore, Batang station is selected as the reference station within the simulated Region II.

Figure 4 and Figure 5 show the wind speed distribution in recurrence interval within the two simulated regions obtained by ratio method. The 50-year-met wind speed is between 20m/s-30m/s in most areas of the simulated Region I, the 100-year-met wind speed is between 20m/s-35m/s, and the wind speed in recurrence interval exceeds 35m/s only in the southwest corner and the scattered high-altitude place. The 50-year-met wind speed is less than 20m/s in most areas of the simulated Region II, the 100-year-met wind speed is less than 25m/s, and the larger wind speed in recurrence interval only occurs in the southwest direction.

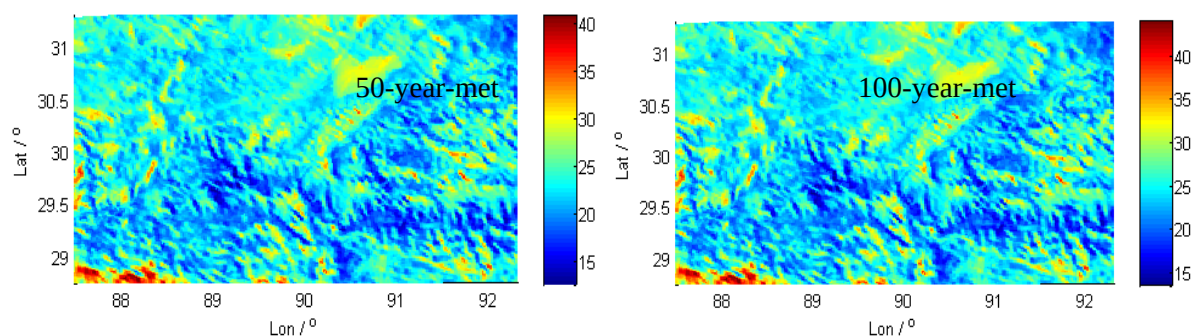


Figure 4. Wind Speed Distribution in Recurrence Interval within Simulated Region I

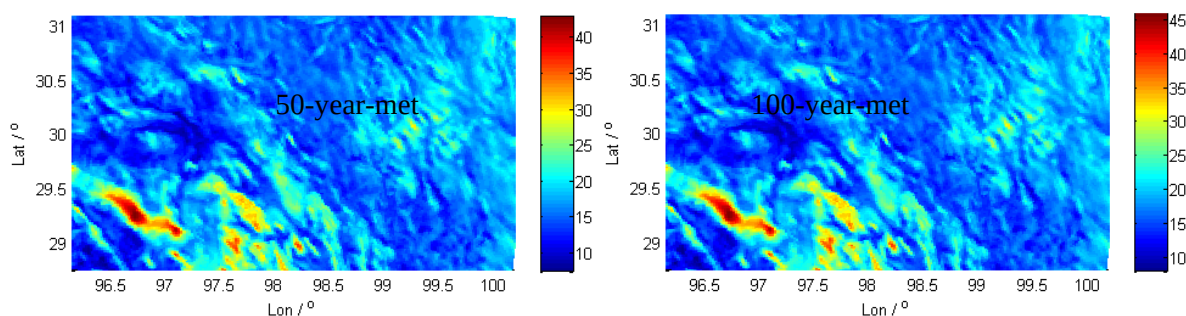
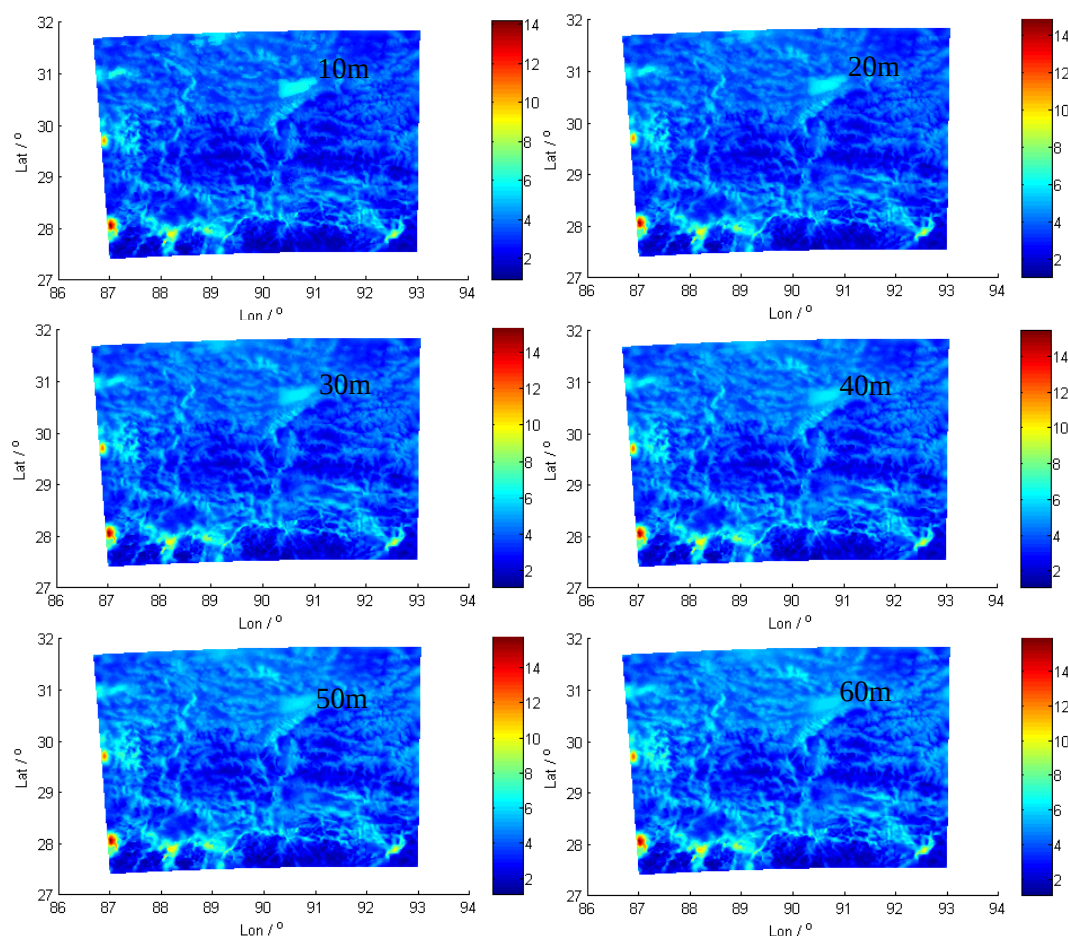


Figure 5. Wind Speed Distribution in Recurrence Interval within Simulated Region II

4.2. Analysis of Average Wind Profile

Figure 6 is the average wind speed distribution of 10m-100m with height interval of 10m within the simulated Region I. The average wind speed is higher in the high-altitude area. There is a larger wind speed area on the west and south side of the simulated Region I. The height of 10m is more obviously affected by the topography. The wind speed is relatively large in the high-altitude area; in addition, the lake area also has larger wind speed. The average wind speed in the simulated regions at height of 10m is not more than 6m/s. The maximum average wind speed of strong wind area exceeds 10m/s outside the west and south side of the simulated Region I.



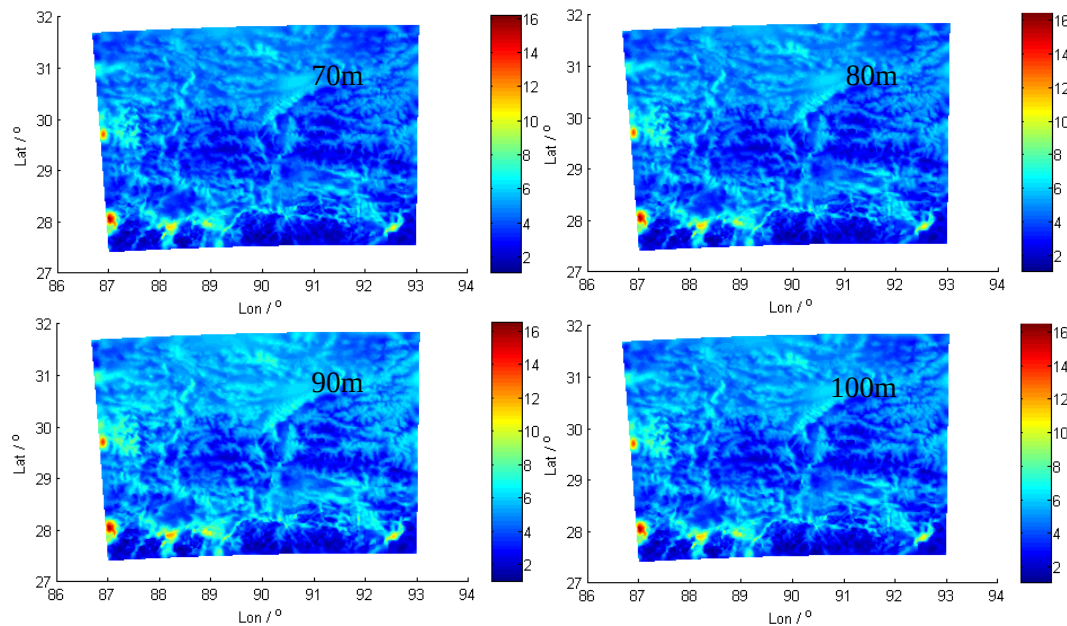
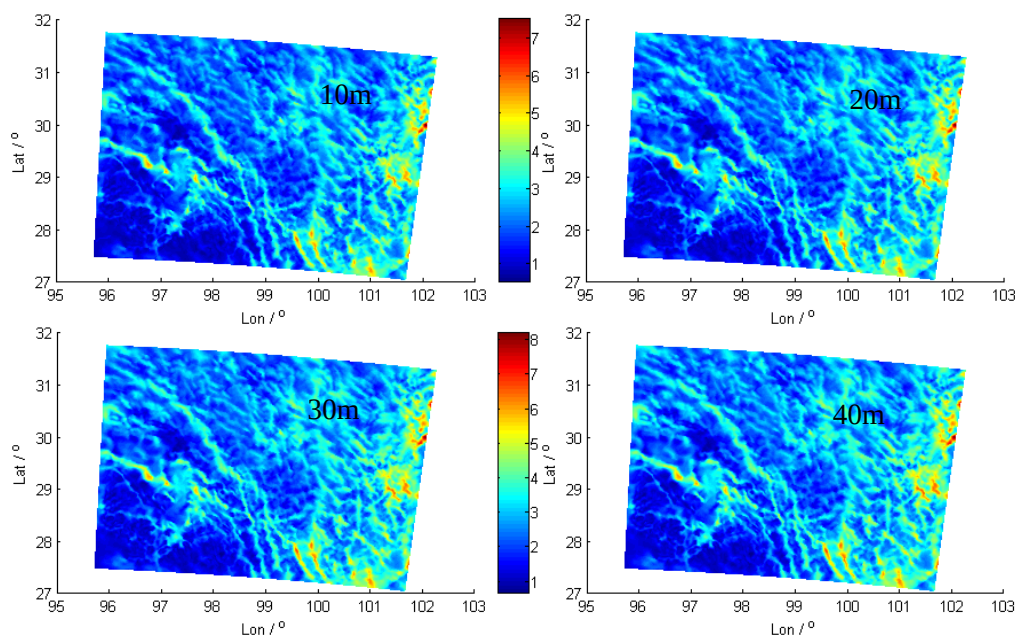


Figure 6. Average Wind Speed Distribution of 10m-100m with Height Interval of 10m Within Simulated Region I

Figure 7 is the average wind speed distribution of 10m-100m with height interval of 10m within the simulated Region II. The average wind speed is higher in the high-altitude area. There is a larger wind speed area outside the east side of the simulated Region II, which may be related to the rapid descent of eastward terrain height in the region. The average wind speed in the simulated region with height of 10m is not more than 6m/s. The wind speed in most areas is less than 4m/s. The maximum average wind speed outside the east side of the simulated Region II is no more than 8m/s. In general, the average wind speed in the simulated Region II is smaller than that of in Region I.



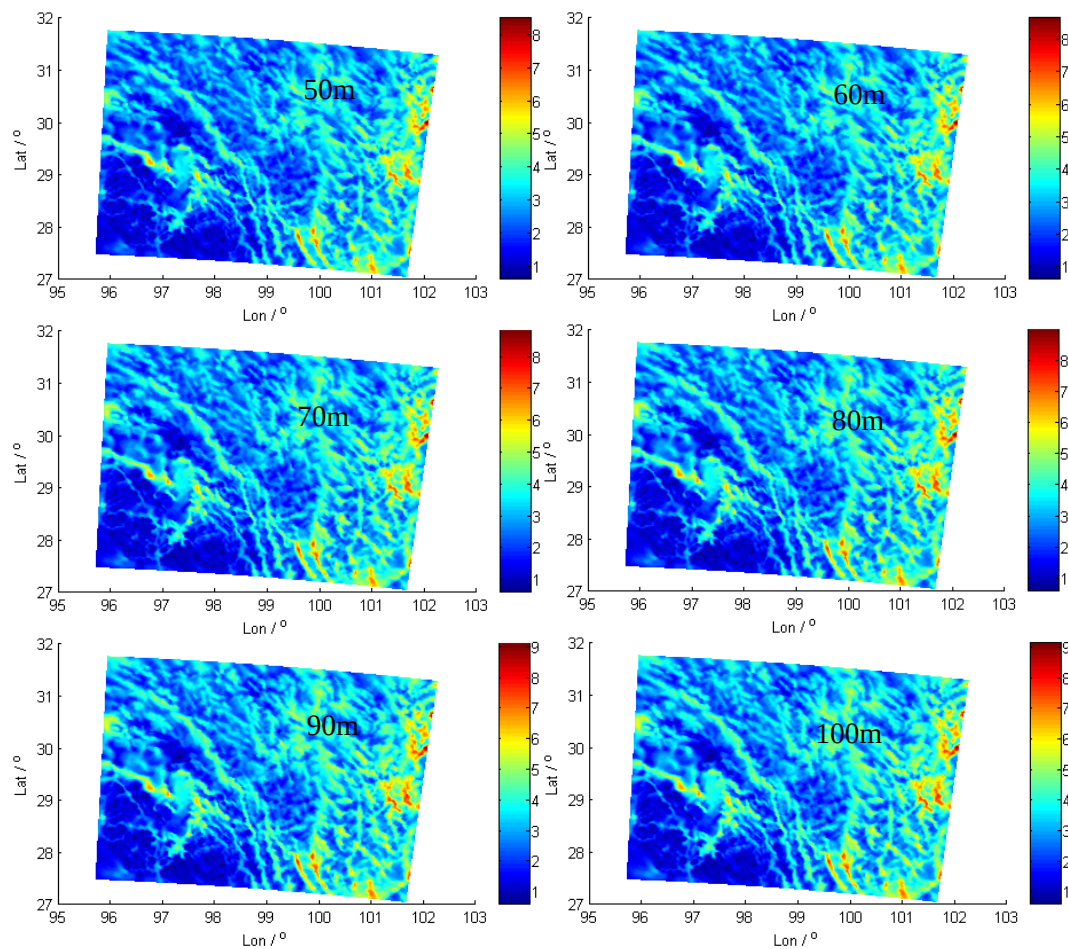


Figure 7. Average Wind Speed Distribution of 10m-100m with Height Interval of 10m Within Simulated Region II

5. Conclusion

This paper conducts the climate model analysis for two regions with densely-deployed transmission lines; captures wind field data at multiple heights within the 10-100m height range; verifies the accuracy of model analysis results based on the actually measured data of meteorological stations and anemometer towers; and reaches the following conclusions by analyzing the mode analysis results:

(1) The 50-year-met wind speed is between 20m/s-30m/s in most areas of the simulated Region I and the 100-year-met wind speed is between 20m/s-35m/s. The maximum wind speed appears nearby Bange Meteorological Station. The 50-year-met wind speed and the 100-year-met wind speed are 28.4m/s and 30.0m/s respectively. The 50-year-met wind speed is less than 20m/s in most areas of the simulated Region II, and the 100-year-met wind speed is less than 25m/s. The maximum wind speed appears nearby Xinlong Meteorological Station. The 50-year-met wind speed and the 100-year-met wind speed are 27.4m/s and 28.9m/s respectively.

(2) Based on geomorphology, the altitude change in the Region I is small and the overall is flat; the altitude change in the Region II is large and the overall is rough. Based on altitude, the altitude in the Region I is higher than that of in the Region II. The wind speed in Region I is slightly higher than that of in Region II under the joint influence of altitude and geomorphology.

(3) The wind speed in the regions I and II change more rapidly with height, compared with the wind speed in lower latitudes. The corresponding wind profile coefficient will be significantly reduced,

which will significantly increase the wind load in tower body especially in tower head, cross arm, and wire.

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