Study on future urban form and land use pattern considering urban warming and depopulation -Scenario making by using concept of potential natural vegetation-


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1. Introduction

In recent year, thermal environment in urbanized area is becoming severe because of urban heat island and global warming. This phenomena is called urban warming. Consequently, it is said that some problems, such as, loss of inhabitant's comfortable life, increasing of the energy consumption for cooling, extreme weather event and health hazard will occur. IPCC Working Group I Contribution to AR5 concluded world average temperature increased 0.85 degree Celsius from 1880 to 2012. In addition, they predict future climate change by making four RCP scenarios. According to these scenarios, average surface air temperature in the world will increase about 4.8 degree Celsius at most by the end of twenty one century.

So, effect of urban warming will become more severe in the future with progress of global warming, and it is necessary to consider the way of adaptation to urban warming in urbanized area in the future.

On the other hand, depopulation trend have started recently in Japan. National Institute of Population and Social Security Research estimated that population in Japan will decrease from 128 million to 87 million by 2060. If this depopulation will continue, a ratio of vacant and low-use land in the city area will increase and density of city area will be lower in the future. Consequently, it is said that some problems, such as, deterioration of living environment, decline of local community and increasing of energy consumption per persons, will occur. In this context, it is said that present sprawled urbanized area should shrink to some areas in the future in Japan.

Therefore, future urban planning in Japan should consider shrinking present urbanized area with adapting future urban warming. One of the way for adapting urban warming is urban planning utilizing climatic potential in the area. In this study, climatic potential means some factors that affecting temperature of the area. First of all, it must be discussed where and how climatic potential exist in the area to realize this urban planning.

Therefore, this study finally aims at making ideal land use distribution from the view point of thermal environment that can use climatic potentials as much as possible in Kanagawa. This paper estimates original climatic environment in Kanagawa by using concept of potential natural vegetation and meso-scale meteorological model. While, present climatic are also calculated in same way. Through the comparison of these two simulation results, the effect of present urbanization on present climate environment and the possibility of urban planning utilizing climatic potential in this area are discussed.

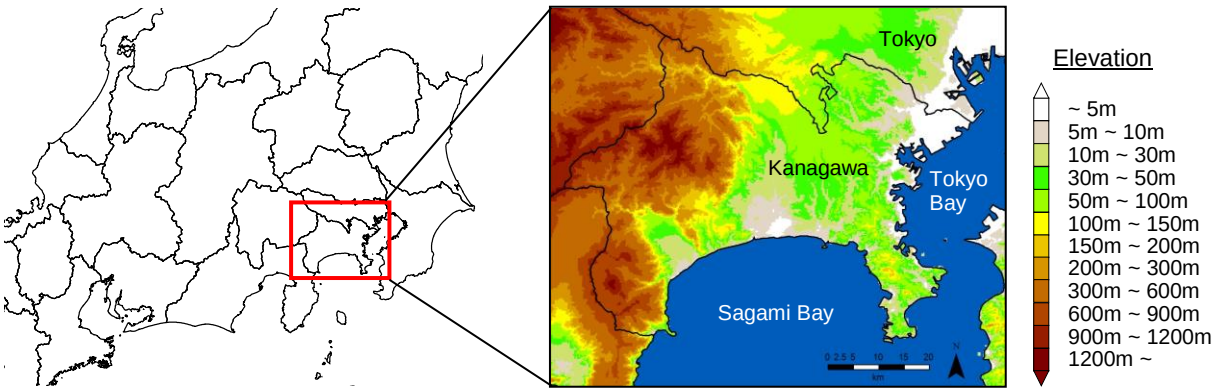

Fig. 1 Target area

2. Outline of research

2.1 Target area

For this study, Kanagawa prefecture is selected as a target area. Figure1 shows the location and elevation of Kanagawa. As shown figure1, Kanagawa prefecture is located in the southwest of Tokyo, and Kanagawa touches Sagami Bay and Tokyo Bay. There are various geographical features in which west part is mountain, center part is plain and east part is tableland. Urban area expand from southwestern part to eastern part of Kanagawa and it's elevation is low(figure2 (a)). Also, eastern part of Kanagawa is near to Central Tokyo. So this area is affected by urban heat island, and it is necessary to mitigate this effect. Basic information related to Kanagawa is given below.

- Area : 2416 [km^2] (2013)
- Population : 9,080,892 [person] (2013)

2.2 Calculation condition

WRF ver3.2.1 ARW is used for this study[1]. Table1 shows the calculation conditions. Two domains are set up, and domain1 is 3km resolution (120*120 grid), domain2 is 1km resolution (103*103 grid). Figure2 shows land-use map of Domain2((a):present condition (b) potential natural vegetation). Present land-use maps is made from the National Land Numerical Information (100m resolution). National Land Numerical Information is different in category, so they are reclassified to 7 categories; i.e. urban area, Irrigated cropland, dryland cropland, mixed forest, water, grass land and bare land. In addition, for urban area, a single urban canopy model[2] is employed. The urban area is classified into three categories; i.e. high building area, low building area and factory, by using ArcGIS Data Collection published by ESRI Japan in 2010. Also, anthropogenic heat from these urban area is shown figure3. This calculation uses some parameters from the research report of countermeasures to heat island by artificial exhaust heat reduction in city area by Ministry of the Environment. On the other hand, concept of potential natural vegetation is used for estimating natural climate condition in the area. Potential natural vegetation is the vegetation that exist after all human activity stop now[3]. The climate that is formed under the potential natural vegetation instead of present land use is called potential natural climate in this study. Land use map of potential natural vegetation is made from potential natural vegetation map. This map classify whole Japan area into potential natural vegetation types, such as beach forest and volcano vegetation. So, all classes are reclassified into 6 categories ;i.e. Shrubland, Deciduous Broadleaf forest, Evergreen Broadleaf forest, Evergreen Needleleaf forest, Water, Herbaceous Wetland, Wooden Wetland, Bare Ground.

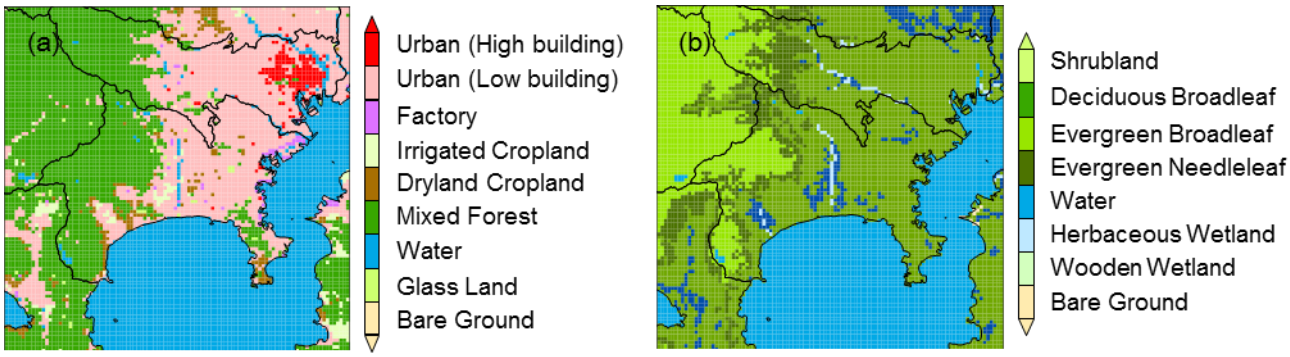

Fig. 2 Land use map of domain2 ((a) present condition (b) under potential natural vegetation)

Table. 1 Calculation condition

Period		August 17-31, 2012
Vertical grid		28 layers（surface ～ 100hPa）
Horizontal grid		Domain1：3km resolution 120×120 grids
		Domain2：1km resolution 103×103 grids
Meteorological data		JMA Meso-scale Analysis（every 3 hour, 10km Grid, 20 layers） NCEP Re-analysis global objective analysis data （every 6 hour, 1° Grid, 17 layers）
Land data	Elevation	Digital Map（50m resolution）
	Land cover	Present : National Land Numerical Information Potential natural climate : Potential natural vegetation map
Microphysics		Purdue Lin et al. scheme
Radiation	Long wave	RRTM Longwave scheme
	Short wave	Dudhia Shortwave scheme
PBL scheme		Mellor-Yamada-Janjic PBL scheme
Surface scheme	Urban area	UCM(Urban Canopy Model)
	Non-urban area	Noah LSM
Cumulus parameterization		none
FDDA		none

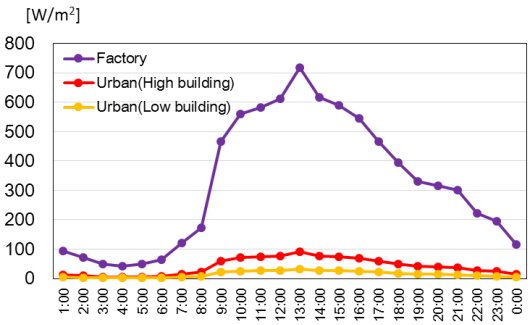

Fig. 3 Anthropogenic heat from urban area

3. Steps of this study

The steps of this study are as follows.
1) Horizontal temperature distributions of present and potential natural climate are analyzed using numerical simulation results.
2) Impact of present urbanization to temperature distribution in Kanagawa is analyzed through comparison of distribution pattern of temperature in present and potential natural climate.
3) Horizontal distribution of wind speed that is considered as one of the factor affecting temperature in Kanagawa and sea breeze front in Kanagawa are mapped.
4) Temperature difference between inside and outside of estimated sea breeze front is analyzed by using statistic method.

4. Results and discussion

4.1 Verification of precision

To verify accurancy of numerical calculation, calculation result of present condition and observational data during calculation period are compared. Observational data used here is automated meteorological data acquisition system(AMeDAS) data and Air pollution monitoring station data in Kanagawa. Specifically, Bias, RMSE and Correlation are calculated every points and the number of temperature and wind observation points is 10 and 11points respectively. Table2, 3 show results of verification of precision. According to these results, although there exists some variation between every points, generally correlation are high and Bias and RMSE is low. So, authors considered numerical calculation in this study mainly can represent climatic characteristic of present Kanagawa.

Table2 . calculation accuracy of temperature

	Point	Bias[℃]	RMSE[℃]	correlation
AMeDAS	Miura	-0.18	1.19	0.90
	Odawara	1.60	2.52	0.91
	Tsujido	0.76	1.27	0.88
	Ebina	1.04	2.09	0.93
	Yokohama	0.23	1.00	0.96
Air pollution monitoring stationdata	Hiratsuka	0.54	1.13	0.88
	Hujisawa	0.78	1.15	0.92
	Nagahama	1.37	1.67	0.95
	Hadano	0.71	1.77	0.91
	Ayase	1.55	2.25	0.95
	Tajima	-0.14	1.15	0.97
	Miho	0.26	1.54	0.92
	Sagamihara	0.18	1.13	0.95
	Nakahara	-0.16	0.82	0.96
	Asou	0.02	1.39	0.92

Table3 . calculation accuracy of wind speed

	Point	Bias[m/s]	RMSE[m/s]	Correlation
AMeDAS	Miura	1.23	1.88	0.47
	Odawara	-0.16	0.62	0.86
	Tsujido	-0.23	1.64	0.43
	Ebina	0.23	0.81	0.81
	Yokohama	-0.53	0.99	0.69
Air pollution monitoring stationdata	Odawara	-1.17	1.44	0.85
	Hiratsuka	0.79	1.34	0.63
	Hujisawa	1.55	1.84	0.46
	Nagahama	0.52	0.81	0.76
	Hadano	0.93	1.42	0.41
	Ayase	-0.53	1.16	0.81
	Tajima	2.39	2.59	0.44
	Miho	-0.37	1.01	0.78
	Sagamihara	-0.99	1.65	0.82
	Nakahara	-0.10	0.77	0.72
	Asou	-0.05	1.03	0.78

4.2 Extraction of sea breeze circulation days

During calculation period, there are two wind patterns in Kanagawa. One is the day on which south wind blow all day in whole Kanagawa, and the other is the day on which sea breeze blow in coastal area and enter to inland gradually. This patterns are mentioned in previous study[4]. During calculation period, the number of south wind day is 7days and sea breeze day is 5days. Also, all sunny day during August 2012 are classified by using AMeDAS Data. As results, the number of south wind days is 10 days and sea breeze day is 13 days. From these results, it is assumed that sea breeze day is typical wind pattern in this area during summer season. Also, figure4 shows average temperature change in urbanized area in two pattern. As shown figure4, temperature of sea breeze day is higher than south wind day, especially during daytime. So sea breeze day is focused in this paper. As for south wind day, it is next work.

4.3 Horizontal distribution of temperature

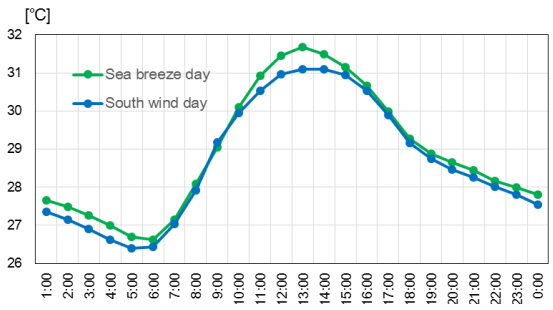

Fig. 4 Average temperature change in two pattern day

Figure5 and 6 show average horizontal temperature distribution of sea breeze day in each conditions. Target area of analysis is urban mesh classified in present land use map. As shown figure5, temperature in coast of Sagami Bay is lower than other area and from about 30 to 31 degree Celsius at 11:00 in present. This is because sea breeze from Sagami bay is entering to inland and effect of sea breeze is appearing in the coast of Sagami bay at this time. At 14:00, temperature in southern coast is not much changed, but temperature in northeastern part of Kanagawa increase and reach to nearly 34 degree Celsius. There is nearly 5 degree Celsius difference between coast and inland. This difference is caused by air cooling effect of sea breeze, urban heat island effect around Central Tokyo and effect of anthropogenic heat from factory in the coast of Tokyo Bay. At 4:00, temperature in coast of Tokyo and Sagami Bay is higher than inland. This is because temperature in inland can fall by radiative

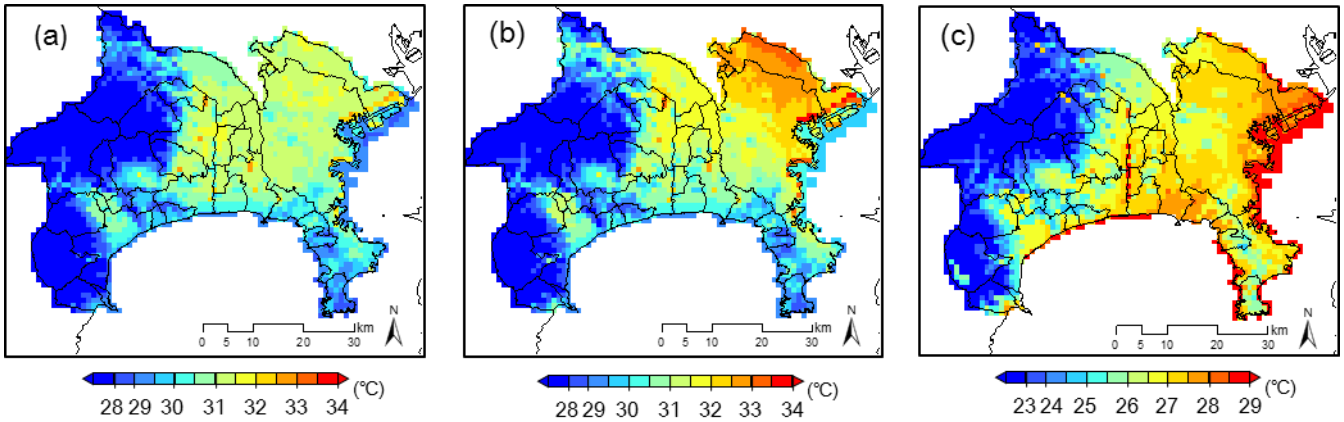

Fig. 5 Average temperature distribution under present condition (a) 11:00 (b) 14:00 (c) 4:00

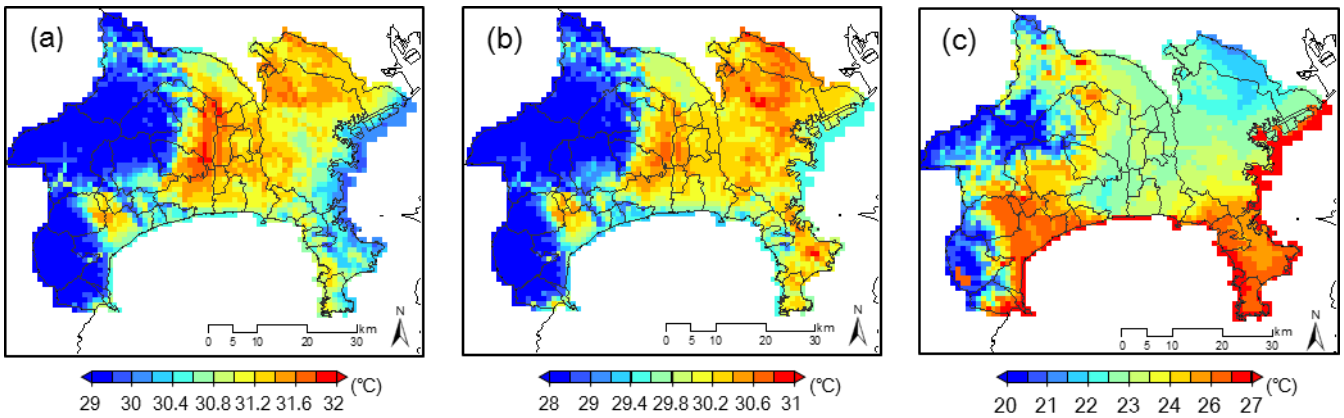

Fig. 6 Average temperature distribution under potential natural climate (a) 11:00 (b) 14:00 (c) 4:00

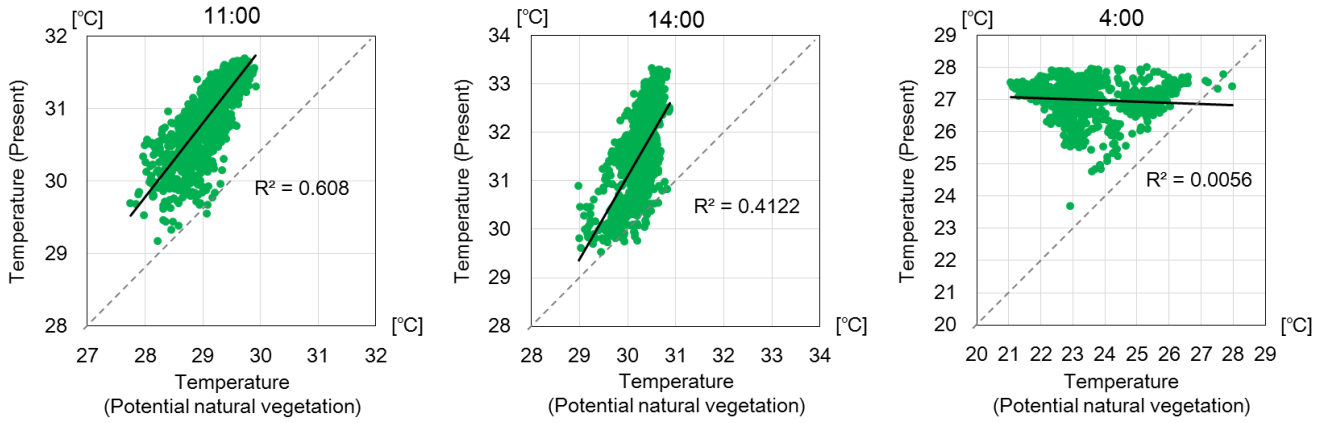

Fig. 7 Relationship of temperature between present and under potential natural vegetation

cooling, while in coast is affected by seawater temperature that is hotter than air temperature. On the other hand, as shown figure6, coast of two bays is cooler than other area as well as present condition at 11:00. But the difference of maximum and minimum temperature in this time is smaller than present. At 14:00, relative high temperature area expands in central and eastern Kanagawa. From this results, this two area is tend to hot during summer daytime potentially. At 4:00, Southeastern and southwestern part of Kanagawa is hotter than other area. According to figure5 and figure6, temperature difference between present and potential natural climate is large during daytime and small during nighttime. So, impact on temperature by present urbanization is large during nighttime in this area.

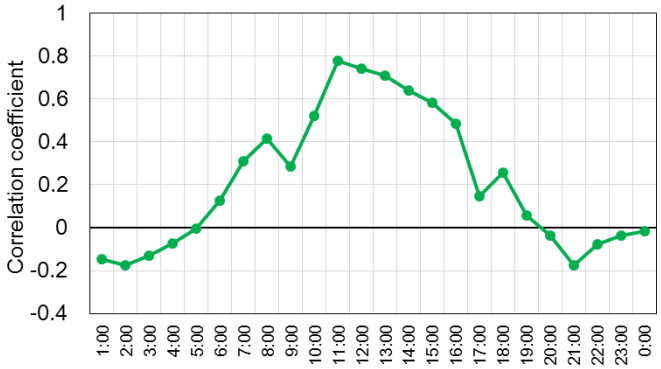

Fig. 8 Correlation change of temperature between present and under potential natural vegetation

4.4 Comparison of distribution pattern

Figure7 shows relationship of temperatures between present and potential natural climate and figure8 shows the time series of correlations between present temperature and potential natural climate. Additionally, these figures are made from the results of urban mesh in present land use map. As shown figure8, correlation during daytime (from 10:00 to 16:00) is high and it's from 0.5 to 0.8. This result means that temperature distribution pattern between present and potential natural climate is generally similar during daytime, and high temperature area in present condition locate the area that temperature tend to increase potentially in Kanagawa during daytime. On the other hand, there is hardly correlation during nighttime(from 19:00 to 6:00). This means two temperature distribution patterns between present and potential natural climate is different during nighttime, and high temperature area in present condition is formed anew by present urbanization in different place from potentially high temperature area. Also, as shown figure7, range of distribution in present is wider than that of potential natural climate.

From these reasons, effect of present urbanization on temperature distribution patterns is large during the nighttime, but this effect is smaller during the daytime relatively. Namely, when an area is urbanized, the temperature after the urbanization is affected by the characteristic that the area has potentially to some extent. So, it is possible that leading urbanized area to some cooler areas that can use climatic potential during daytime when we think about future land use in Kanagawa. In the next chapter, wind speed is analyzed as one of the factors that can affect temperature in this area during daytime in this area.

5 Analysis of climatic potential

5.1 Relationship to temperature and wind speed

Figure9 shows the relationship between temperature and wind speed at 12:00 in present condition. And figure10 shows correlation change between temperature and wind speed in present condition. As shown these figures, there is negative correlation during daytime(10:00 - 17:00). Namely, high wind speed area have low temperature during daytime. Also, magnitude of correlation start decreasing from 14:00. This is considered that sea breeze from Sagami and Tokyo Bays start to blow from 10:00 in coast and enter to inland until 13:00 gradually and sea breeze cover whole Kanagawa and difference of wind speed become small after 13:00. From these things, gathering urbanized area in Kanagawa with focus on these area have large wind speed in urban area during daytime.

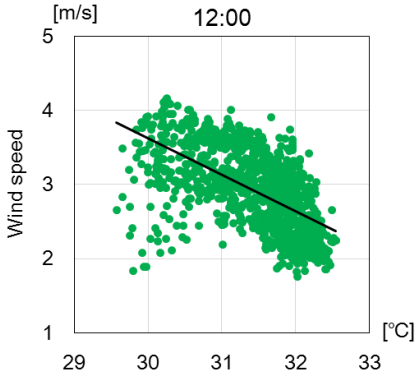

Fig. 9 Relationship between temperature and wind speed

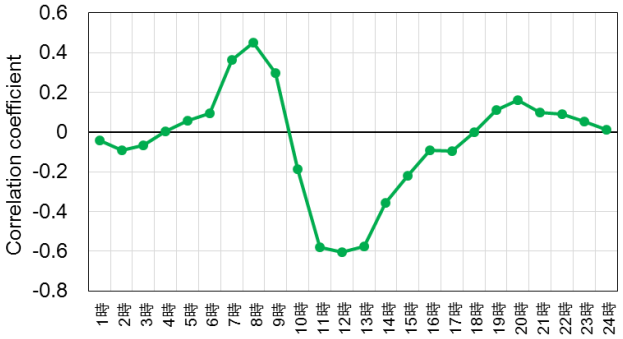

Fig. 10 Correlation change between temperature and wind speed

5.2 horizontal distribution of wind

Figure11 and 12 show average horizontal wind direction and wind speed distribution of the days when sea breeze blow from Sagami and Tokyo Bay in each conditions. As shown figure11, sea breeze blow Sagami Bay and Tokyo Bay at 11:00 in present condition. Wind speed is higher in coastal area of Sagami and Tokyo Bay. Specifically, these area expand from about 10km from two coastline and wind speed is about 3.0m/s in Sagami Bay coastal area and 2.5m/s in Tokyo Bay coastal area. This is considered intrusion area of sea breeze. Two sea breeze blow from two bays at 12:00 as well as 11:00. But intrusion area of sea breeze expand to more inland than 11:00. Especially, sea breeze from Sagami Bay become more strong than sea breeze from Tokyo Bay. At 14:00, south wind prevail whole urbanized area and wind speed is low in northeastern part of Kanagawa.

On the other hand, in potential natural climate, sea breeze brow from two bays as well as present condition. But wind speed is lower than present condition at 11:00. In potential natural climate, temperature of land area doesn't increase so that there is no urbanized area and all area covered potential natural vegetation. So, temperature difference of land area and sea decrease, and power of sea breeze become smaller than present condition. At 12:00, distribution don't change much compared with 11:00. This is because sea breeze circulation is hard to

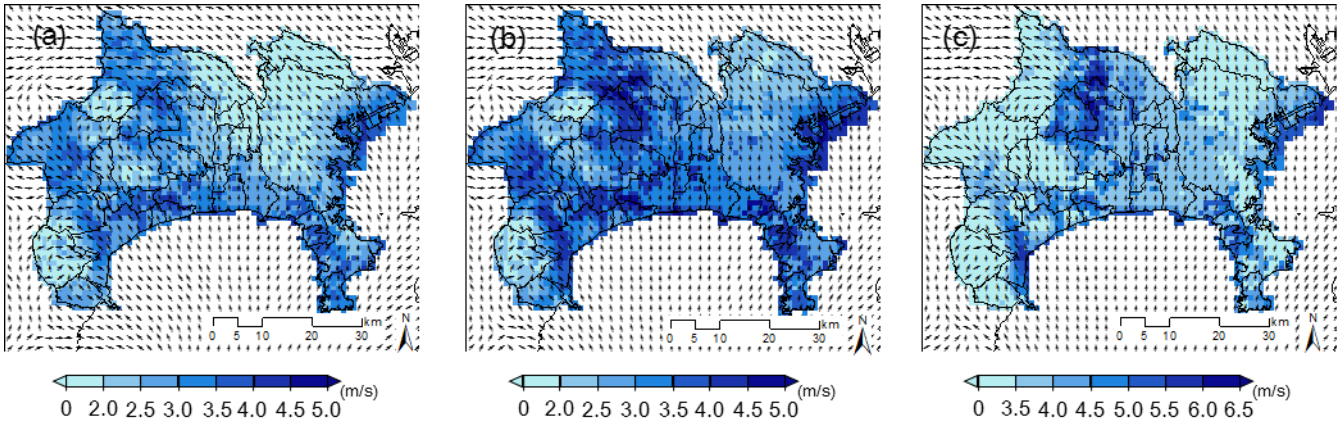

Fig. 11 Average wind distribution under present condition (a) 11:00 (b) 12:00 (c) 14:00

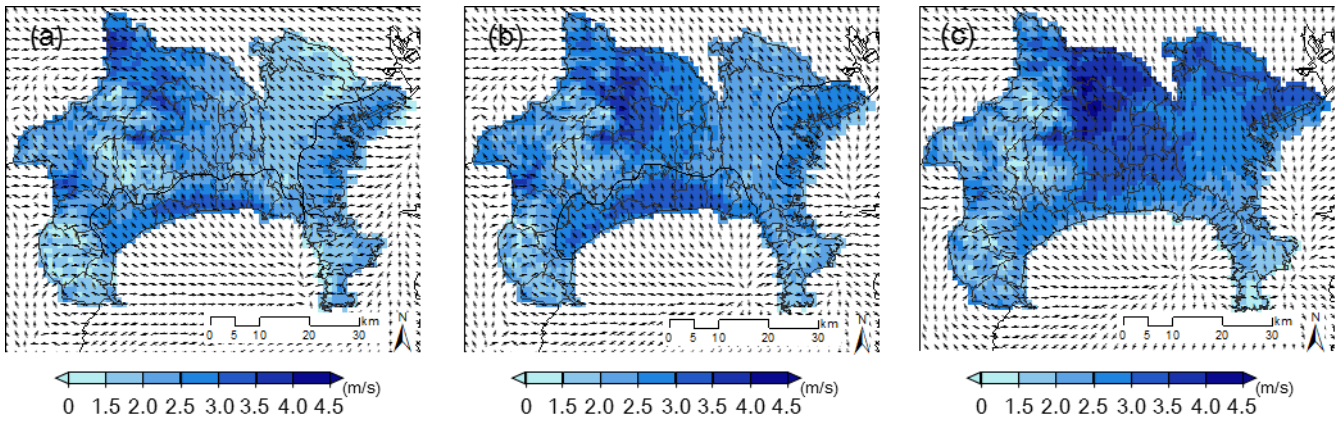

Fig. 12 Average wind distribution under potential natural climate (a) 11:00 (b) 12:00 (c) 14:00

develop because the difference of temperature doesn't increase at this time. At 14:00, wind speed is higher northern part of Kanagawa and lower in the coast of Sagami Bay. This is considered caused by valley wind that blow from plane area to mountain valley. From these things, sea breeze front in potential natural climate is estimated(figure12).

Finally, temperature difference between inside and outside of sea breeze front is checked for confirming whether it is significant difference statistically or not. Specifically, independent t-test is used every hour and sample data is average temperature inside and outside of sea breeze front for every hours. Additionally, significance level is 5%. As a result, two average temperature from 10:00 to 17:00 is significant different statistically. Therefore, building urbanized area inside sea breeze front estimated in this study can realize urban planning using temperature reduction effect caused by the sea breeze.

5. Summary

In this paper, impact of present urbanization and feasibility of land use pattern for using climatic potential in Kanagawa are studied by using concept of potential natural vegetation. As results, there is a correlation between temperatures of present and potential natural climate during daytime in Kanagawa. And temperature after urbanization is affected by characteristic of temperature the area originally had. Therefore, possibility of utilizing climatic potential and ideal land use distribution from the view point of thermal environment during daytime are showed. Also, wind speed that is one of the factors affecting temperature in this area is analyzed. And there is a significant temperatures difference between inside and outside of estimated sea breeze front. From this result, it is considered building urbanized area inside sea breeze front estimated in this study can realize urban planning using temperature reduction effect caused by the sea breeze. Next work is making land use plan from this results and calculating climate condition under such land use.

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