Urban Climate Zoning for Making "Hint Map for Urban Planning"

Analysis on the effect of sea breeze on summer diurnal temperature distribution pattern in Hiroshima plain

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Background

Urban heat island phenomenon

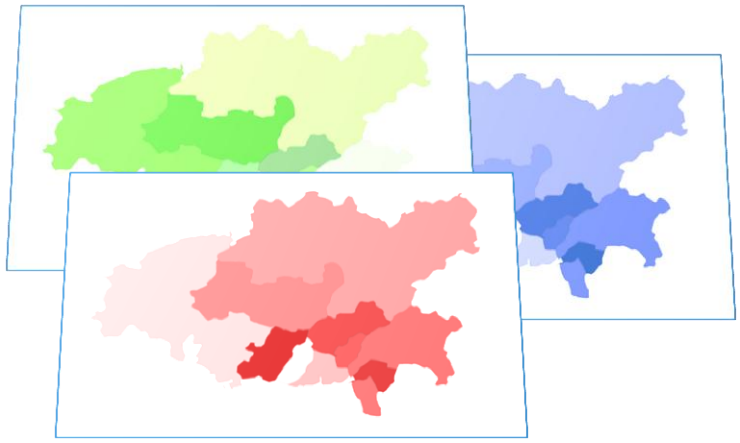
Global warming

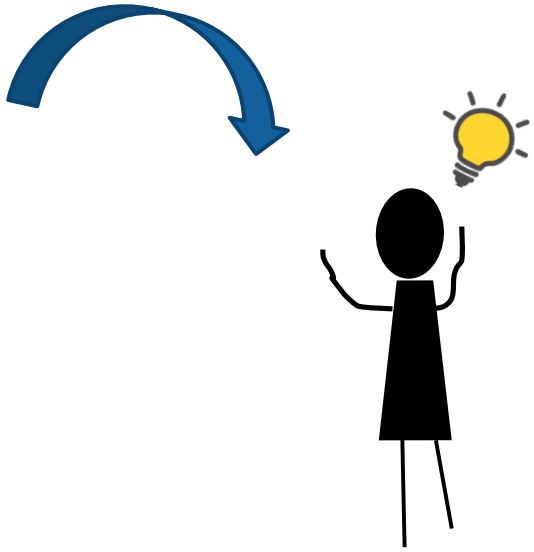
Urban warming

Urban Environmental Climate Maps (UECMs) are proposed as one of the decision support tools for the mitigating urban warming.

Background

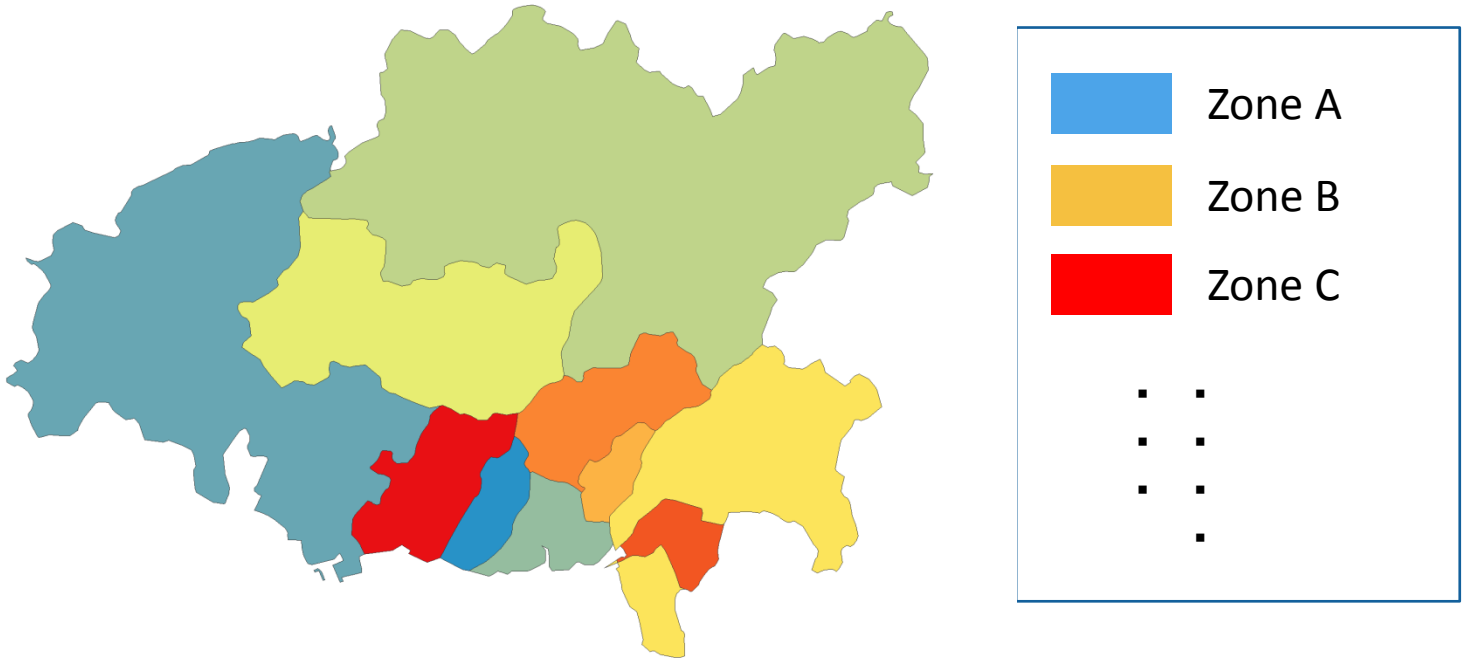
UECMs can be used when stakeholders (citizen, planner, architect, specialist, and so on.) make decision on urban planning, architecture design, and environmental policy making.





Background

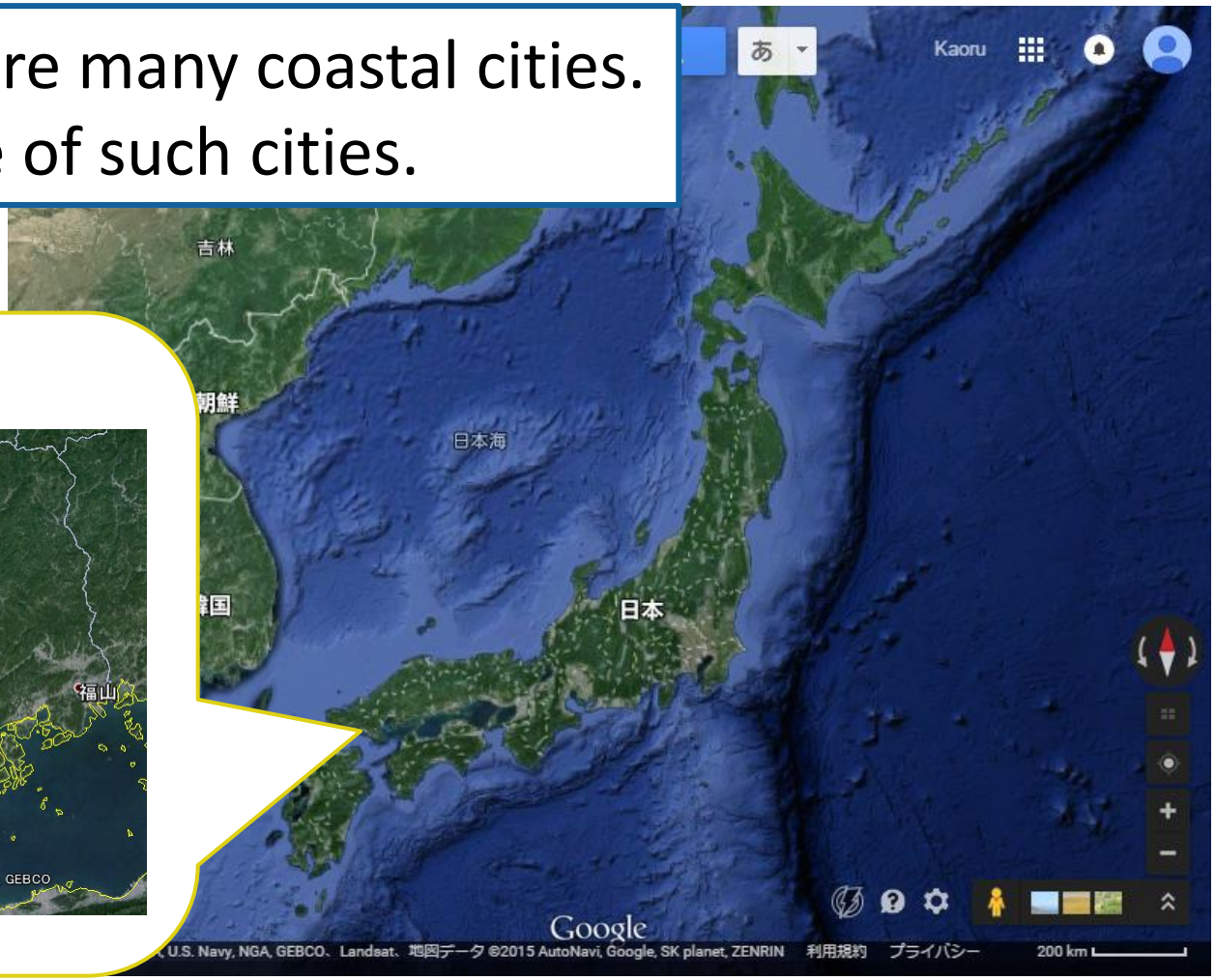
It is effective to indicate the recommendations and climatic resources for each zone which is classified from a climatic perspective.



Background

In Japan, there are many coastal cities.
Hiroshima is one of such cities.

Hiroshima



Background

In Hiroshima, the sea breeze seems to have great influence on summer diurnal temperature distribution patterns.

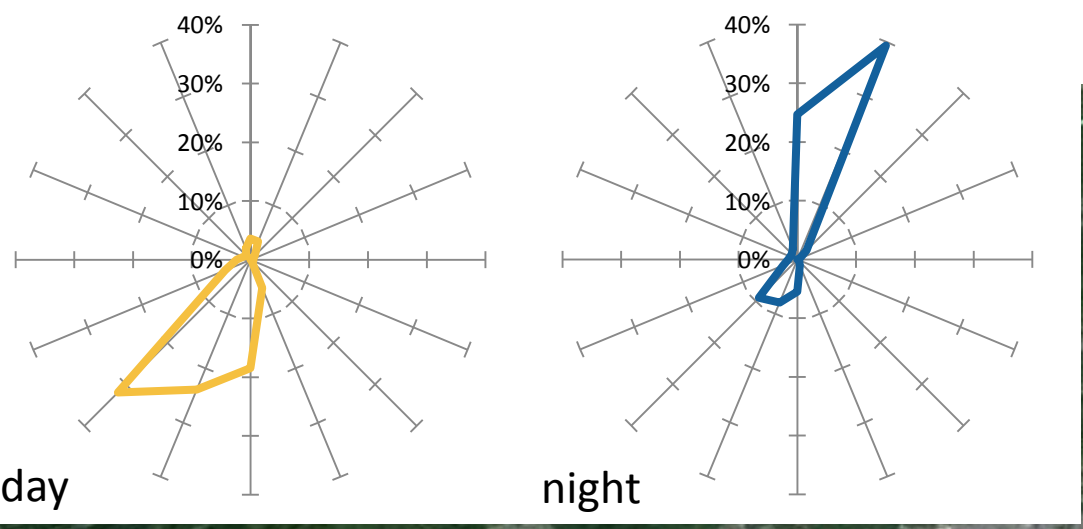
Objective

Understanding the spatial distribution of sea breeze effects will be helpful for making UECMs.

This study aims at making the maps of sea breeze effect distribution in Hiroshima plain.

Observed data

Numerical simulation results



Elev. : 750m

Elev. : 30m

安佐北区

安佐南区

20km

広島県

広島

Hiroshima plain

佐伯区

Sea

Image © 2015 TerraMetrics

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画像取得日: 2014/11/5 34° 25'45.50" N 132° 26'37.03" E 標高 148 m

安佐南区

広島県

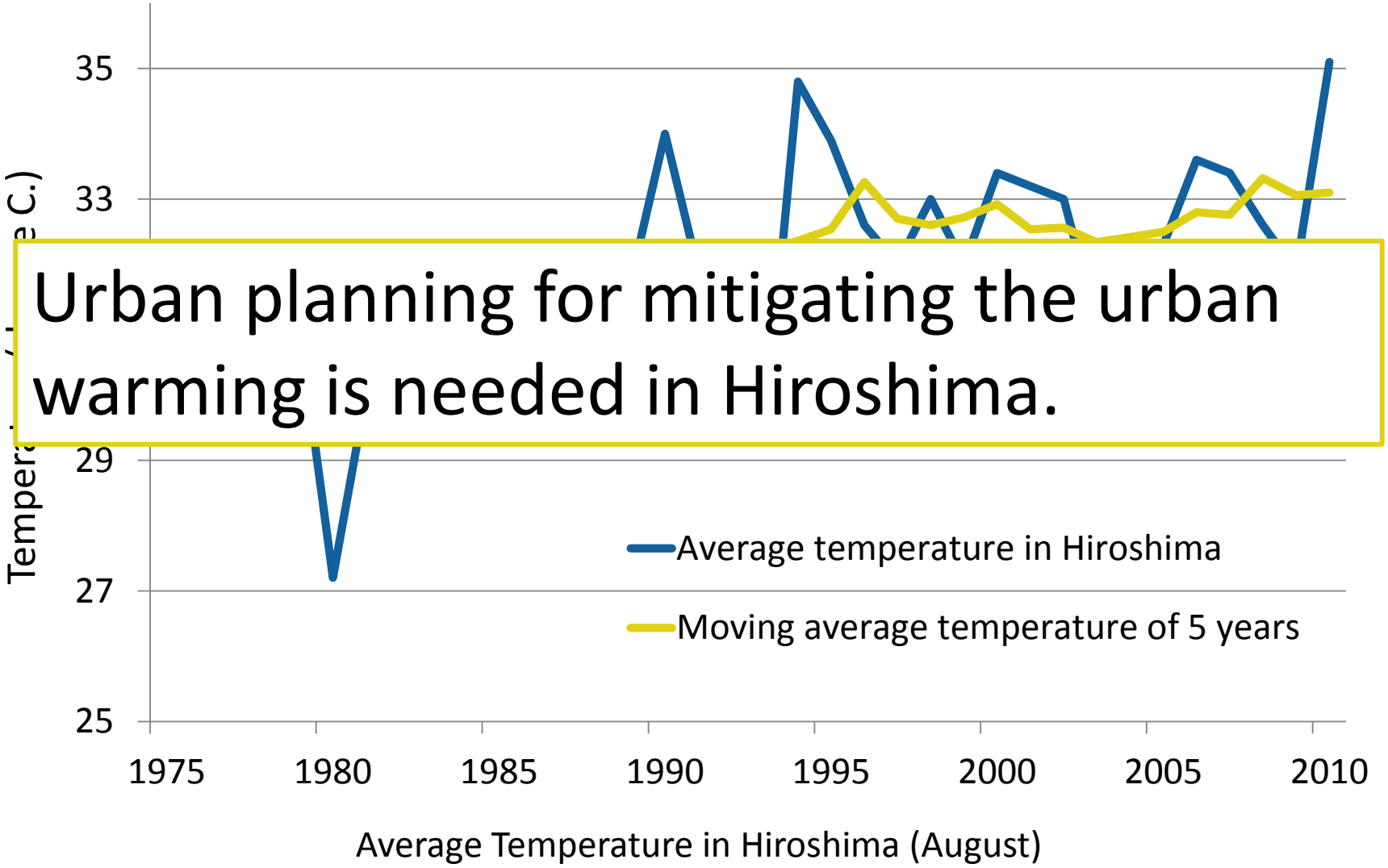
広島

佐伯区

Sea

画像取得日: 2014/11/5　34° 25'45.50" N 132° 26'37.03" E 標高　148 m

Background



Urban planning for mitigating the urban warming is needed in Hiroshima.

Local meteorological observatory (1975-2011)

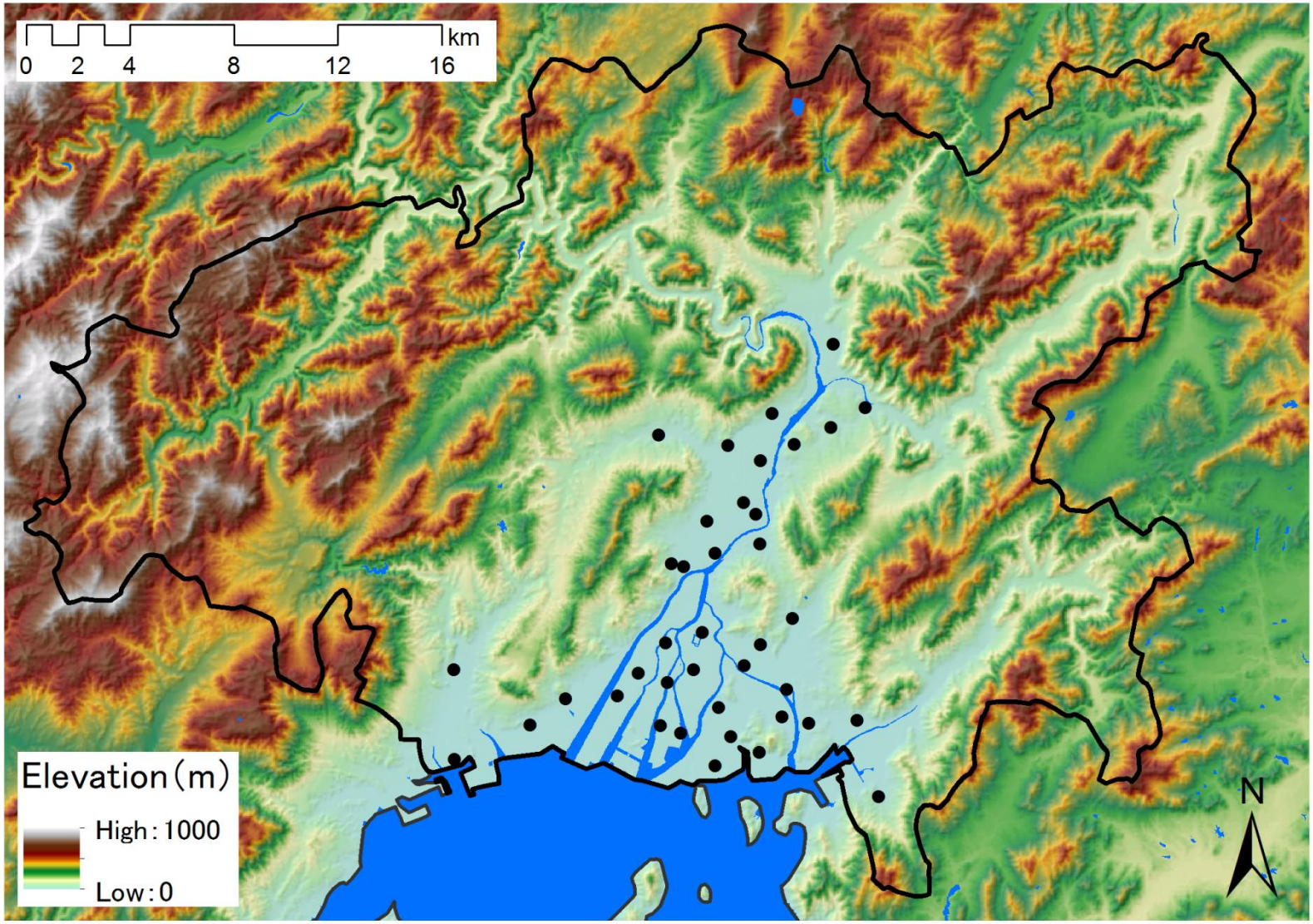
Method

1. Understanding the sea breeze effect distribution using the observed temperature of 39 points.

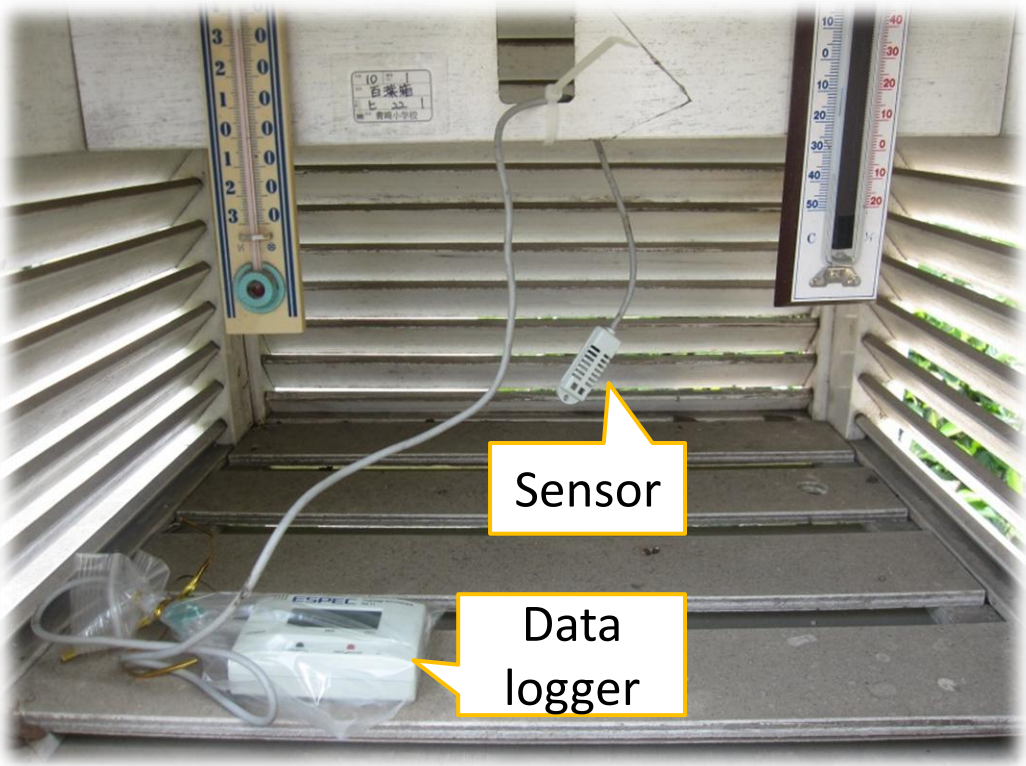
2. Making the map of the sea breeze effect distribution using the meso-scale meteorological model.

3. Analyzing the relationship between the observed temperature and the local ventilation conditions.

Outline of observations



Outline of observations



Period : July 20, 2013 - September 23, 2013
Interval : 20 minutes

This is in elementary school in Hiroshima.

Extracting fine weather days

Period （July 20, 2013 – September 23, 2013）

July						
S	M	T	W	T	F	S
						20
21	22	23	24	25	26	27
28	29	30	31			

August						
S	M	T	W	T	F	S
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

September						
S	M	T	W	T	F	S
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23				

The typical summer fine weather days (35 days) were extracted from the all data (66 days) in the observation period by using the local meteorological station data.

Extracting fine weather days

Typical summer fine weather days (35 days)

July						
S	M	T	W	T	F	S
						20
21	22	23	24	25	26	27
28	29	30	31			

August						
S	M	T	W	T	F	S
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

September						
S	M	T	W	T	F	S
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23				

Criteria

- Daily precipitation is within 1 mm.
- Daylight hours are 40 % or more of the possible duration of sunshine.
- Daily maximum temperature is 30 degree C. or more.
- The weather is not rainy.

Daily wind patterns classification

Wind blowing patterns classification was performed by using the proposed method in the previous research.

July

S	M	T	W	T	F	S
						20
21	22	23	24	25	26	27
28	29	30	31			

August

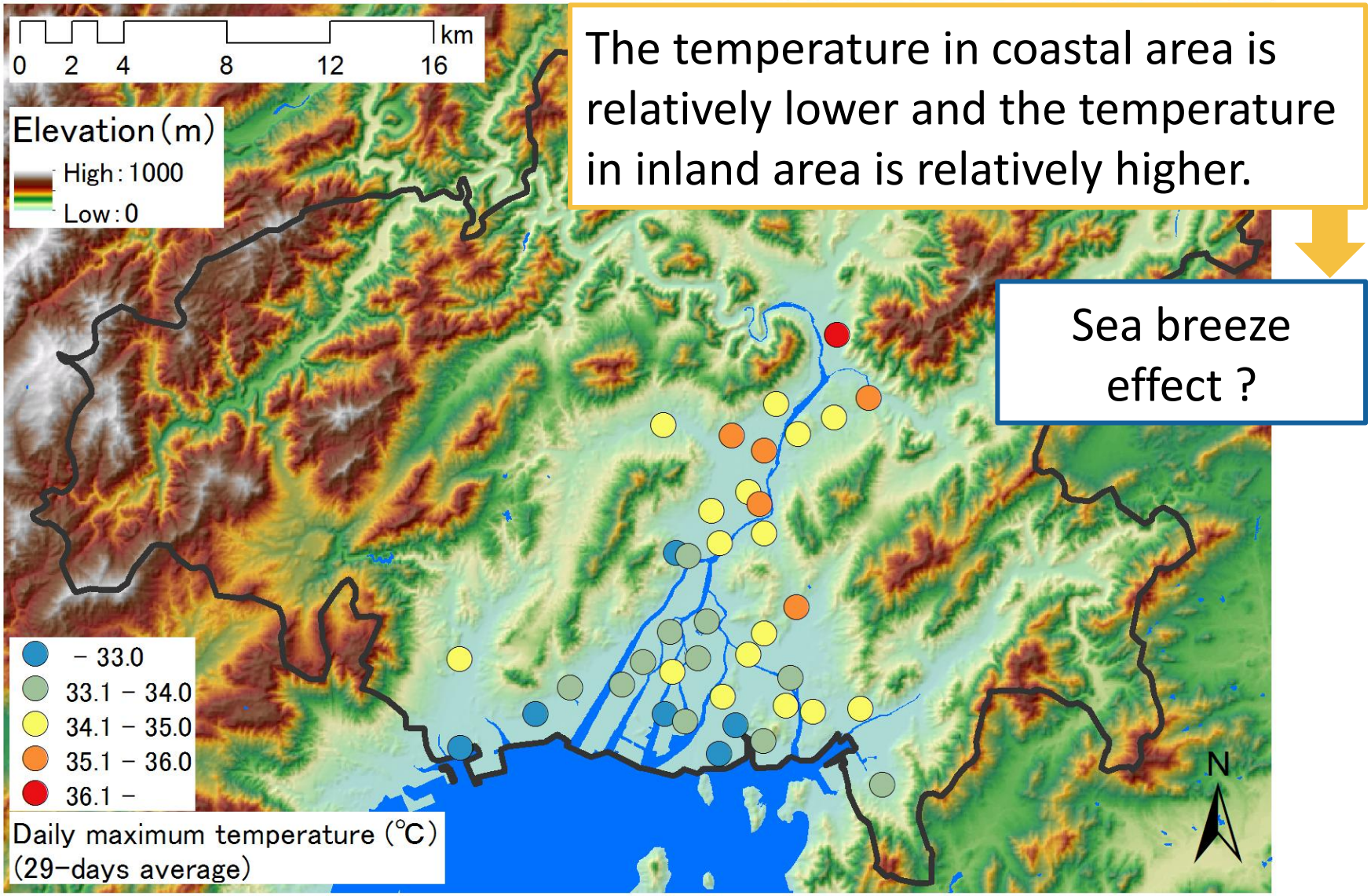
S	M	T	W	T	F	S
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

September

S	M	T	W	T	F	S
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23				

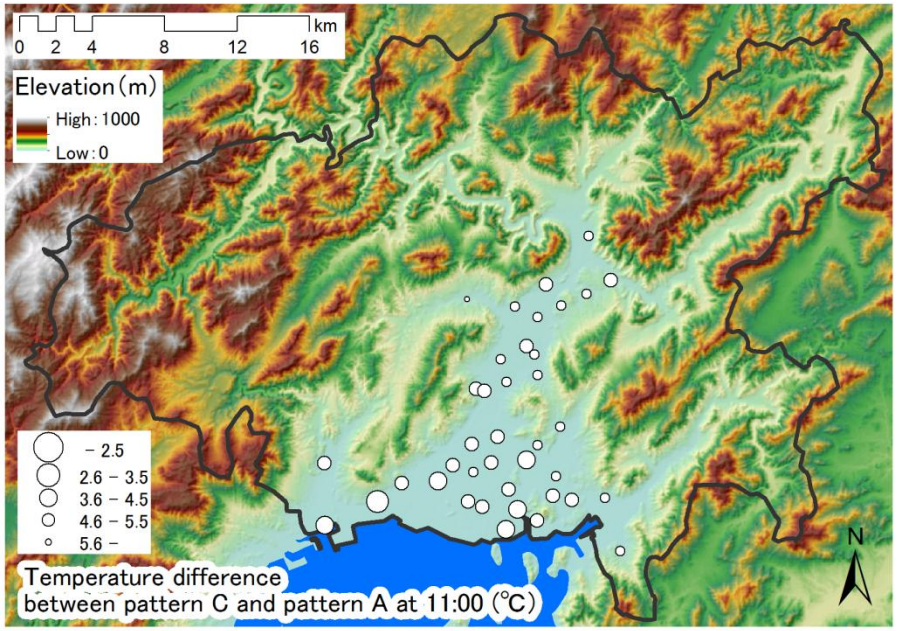
Pattern A	Pattern B	Pattern C
Sea breeze doesn't blow (2 days)	Sea breeze blows, but land breeze doesn't blow (4 days)	Land and sea breeze blow (29 days)

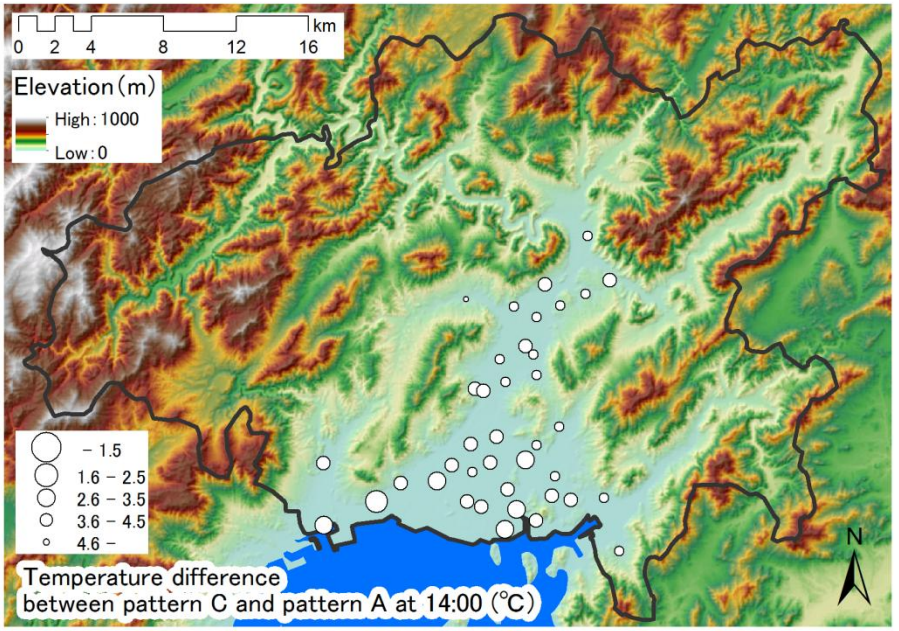
Results of observations (Pattern C)



The sea breeze effect distribution

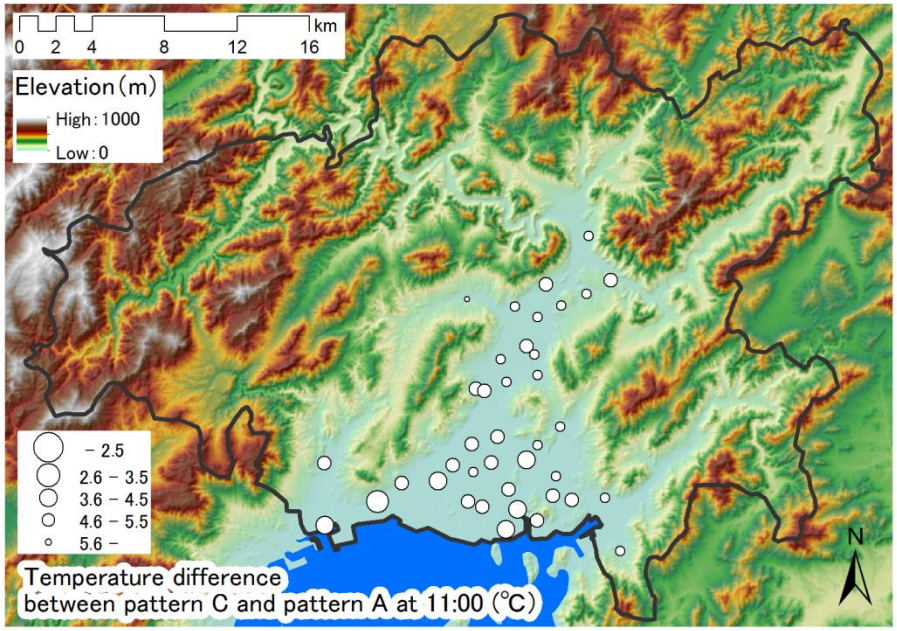
The observed temperature difference between pattern C (the days that land and sea breeze blow) and pattern A (the days that sea breeze doesn't blow) is calculated by using the method proposed in previous research.

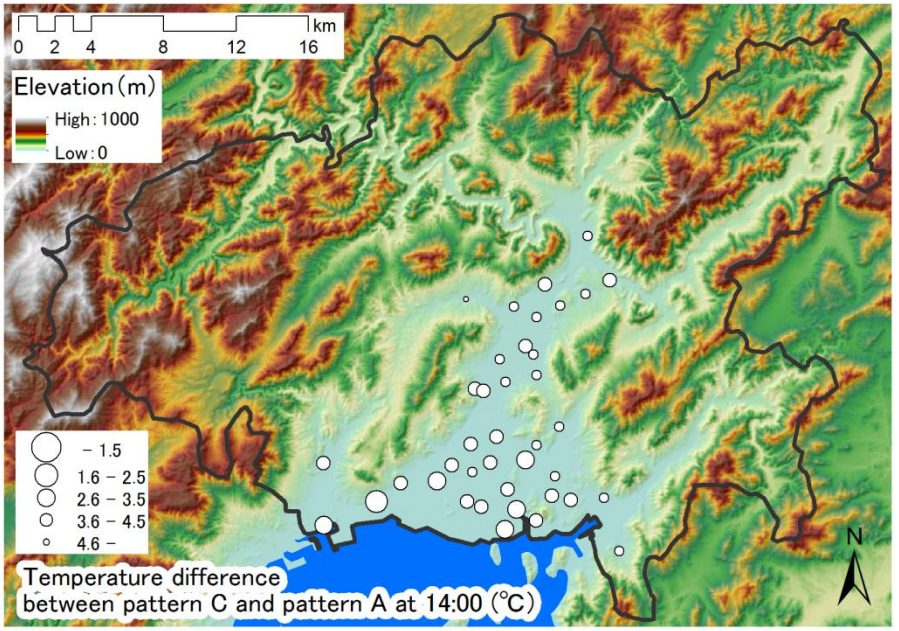




The sea breeze effect distribution

From these figures, it can be seen that the effect of sea breeze for mitigating urban warming is relatively larger in coastal area and the effect is smaller in inland area.





Method

1. Understanding the sea breeze effect distribution using the observed temperature of 39 points.

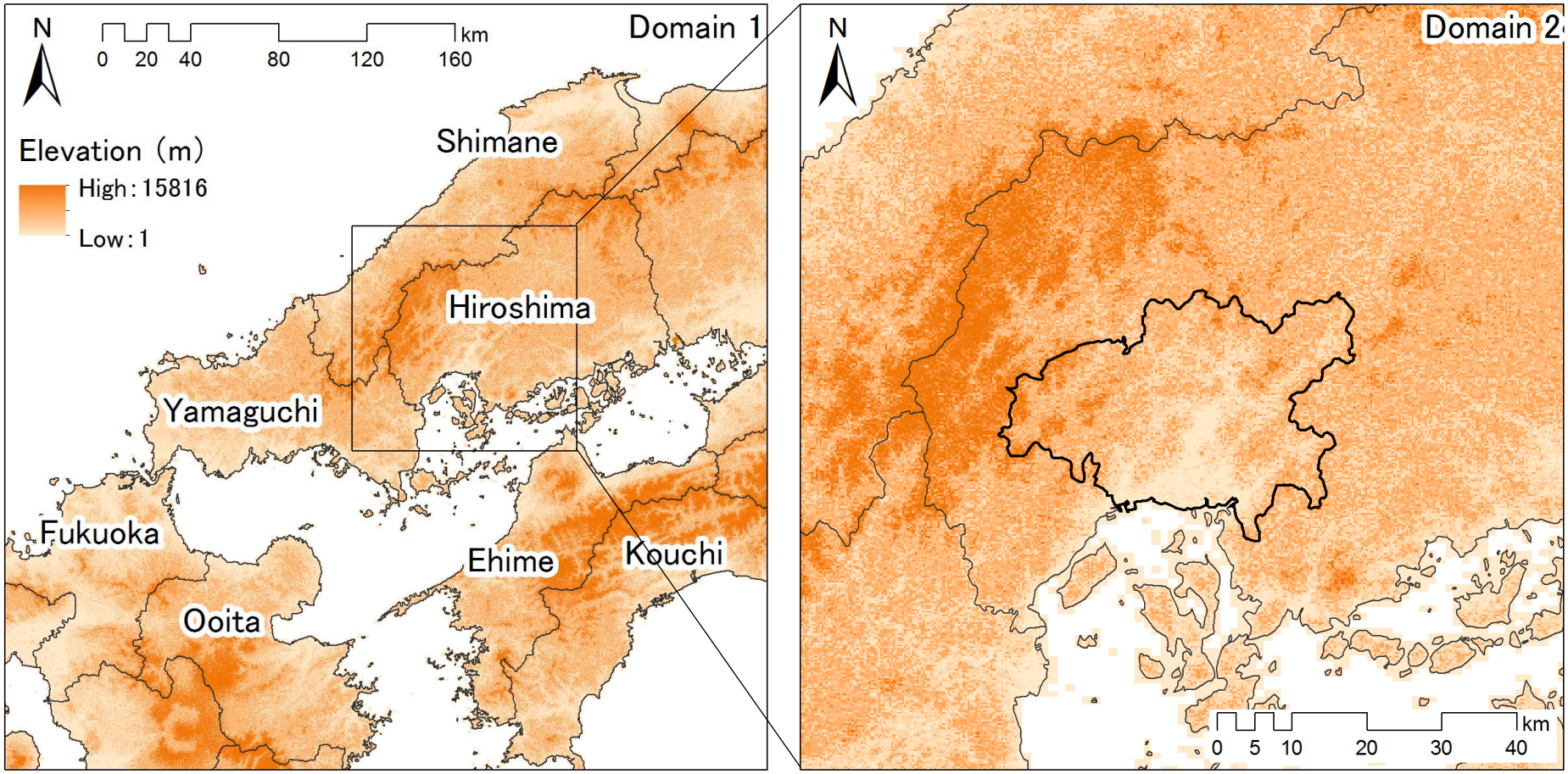
2. Making the map of the sea breeze effect distribution using the meso-scale meteorological model.

3. Analyzing the relationship between the observed temperature and the local ventilation conditions.

Used model and calculation condition

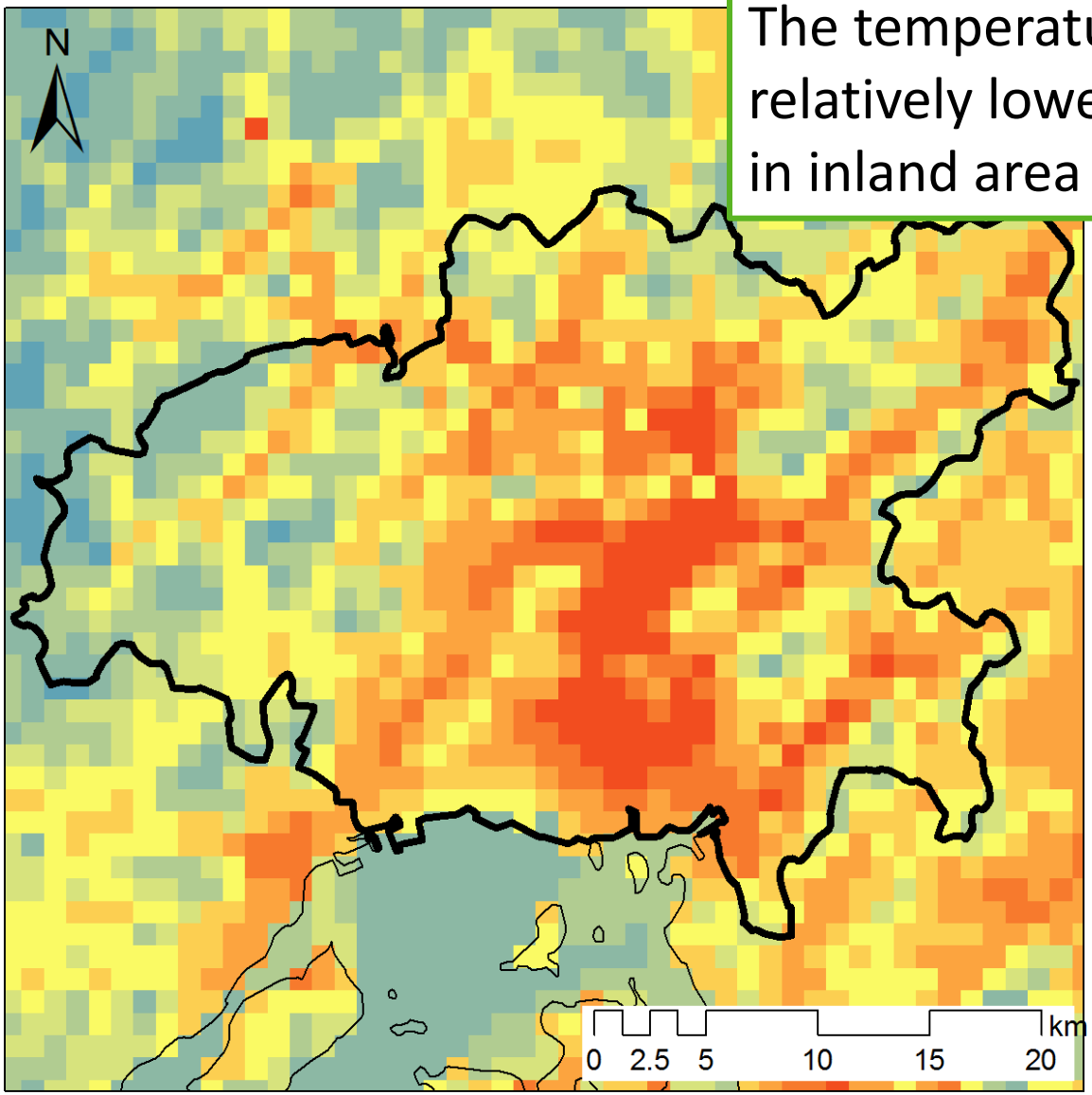
Period		August 4-17, 2013 and August 30- September 12, 2013
Vertical grid		28 layers （Surface ～ 100hPa）
Horizontal grid		Domain1：3km dimension 120×120, Domain2：1km dimension 103×103
Meteorological data		Meteorological Agency Meso Objective Analysis Data （every 3 hour, 10km grid, 20 layers） NCEP Re-analysis global objective analysis data （every 6 hour, 1°Grid, 17layers）
Land data	Elevation	Numerical Map （Resolution about 250）
	Land cover	Digital National Land Information （Resolution about 100） Land cover mesh data in urban area of Digital National Land Information （Resolution about 100） Building use data of Basic Surveys Concerning City Planning in Hiroshima city Data collection of Arc GIS（Esri Japan Corporation） Actual vegetation map of Ministry of the Environment
Microphysics		Purdue Lin scheme
Radiation	Long wave	Rapid Radiative Transfer Model （RRTM） Longwave
	Short wave	MM5（Dudhia） Shortwave
PBL scheme		Mellor-Yamada-Janjic PBL
Surface scheme	Urban area	Urban Canopy Model （UCM）
	Nonurban area	Noah LSM
Cumulus parameterization		None
FDDA		None

Usage model and calculation condition



Results

The temperature in coastal area is relatively lower and the temperature in inland area is relatively higher.

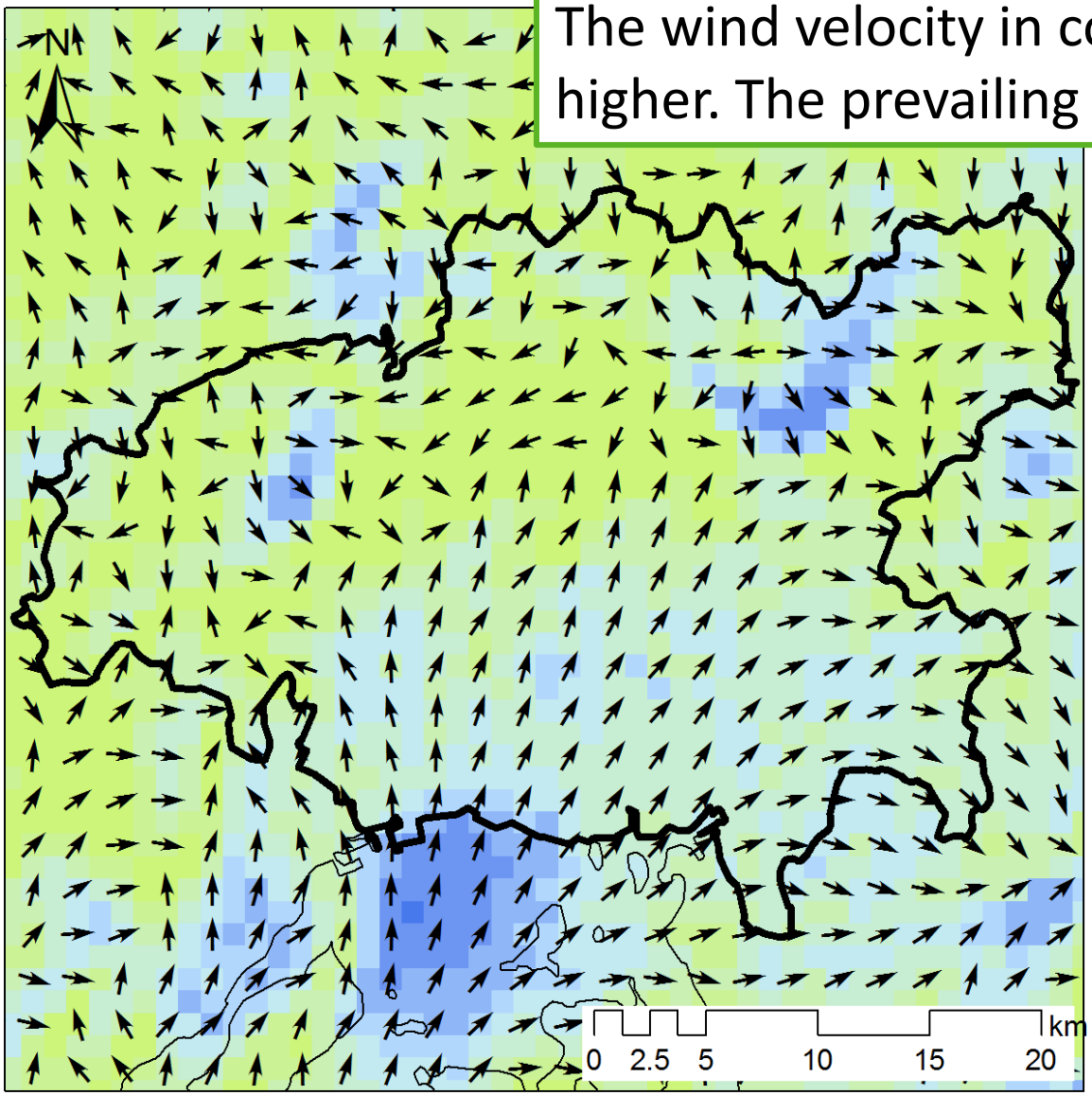


Temperature (℃)
14:00, August 13

- 25.0
25.1 – 27.0
27.1 – 29.0
29.1 – 30.0
30.1 – 31.0
31.1 – 32.0
32.1 – 33.0
33.1 – 34.0
34.1 – 35.0
35.1 – 36.0
36.1 –

Results

The wind velocity in coastal area is relatively higher. The prevailing wind is from the SSW.



Wind Direction

Wind Velocity (m/s)
14:00, August 13

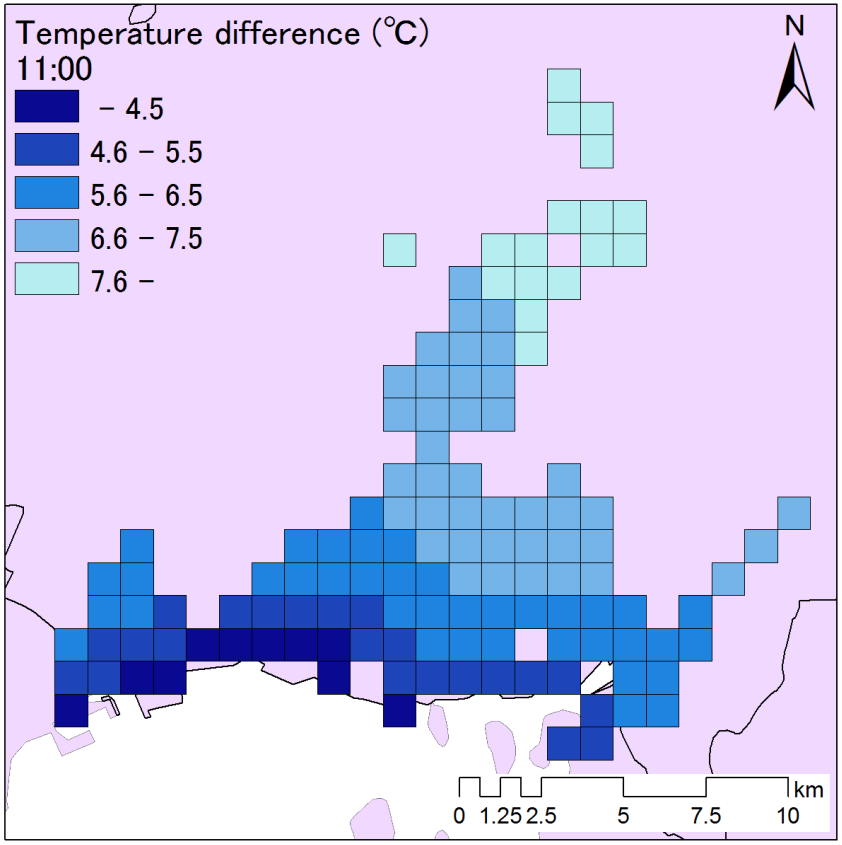
- 1.5
1.6 – 2.0
2.1 – 2.5
2.6 – 3.0
3.1 – 3.5
3.6 – 4.0
4.1 – 4.5
4.6 – 5.0
5.1 – 5.5
5.6 –

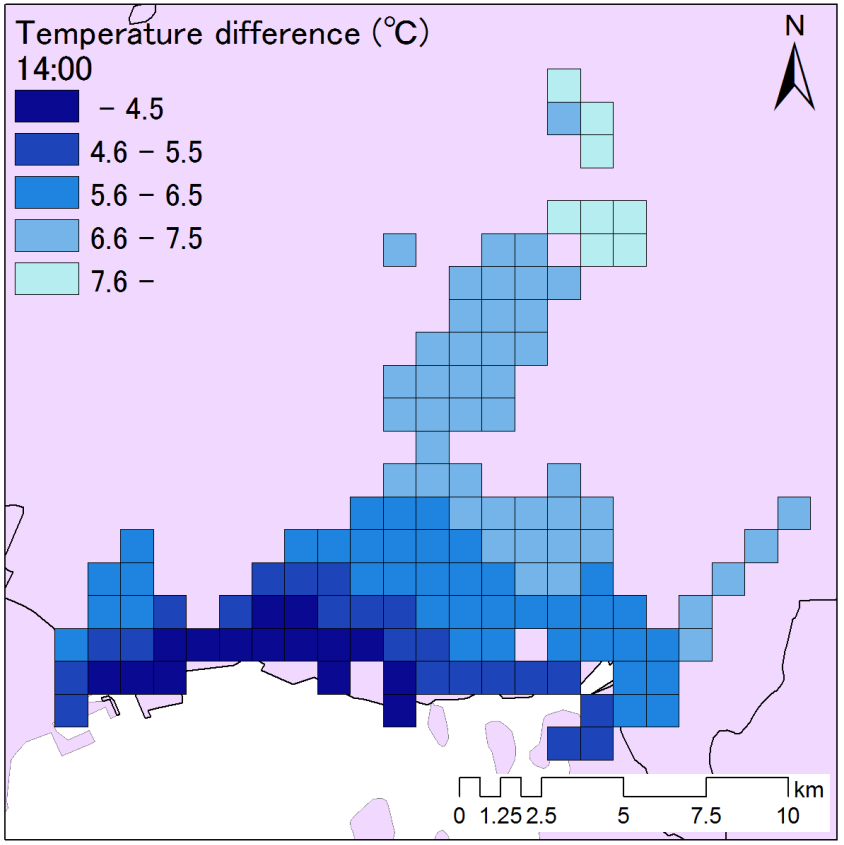
The sea breeze effect distribution

The temperature difference between “the days that sea breeze blows (Average in Aug. 10-16)” and “the days that sea breeze doesn’t blow (Sep. 5)” is calculated.

The sea breeze effect distribution

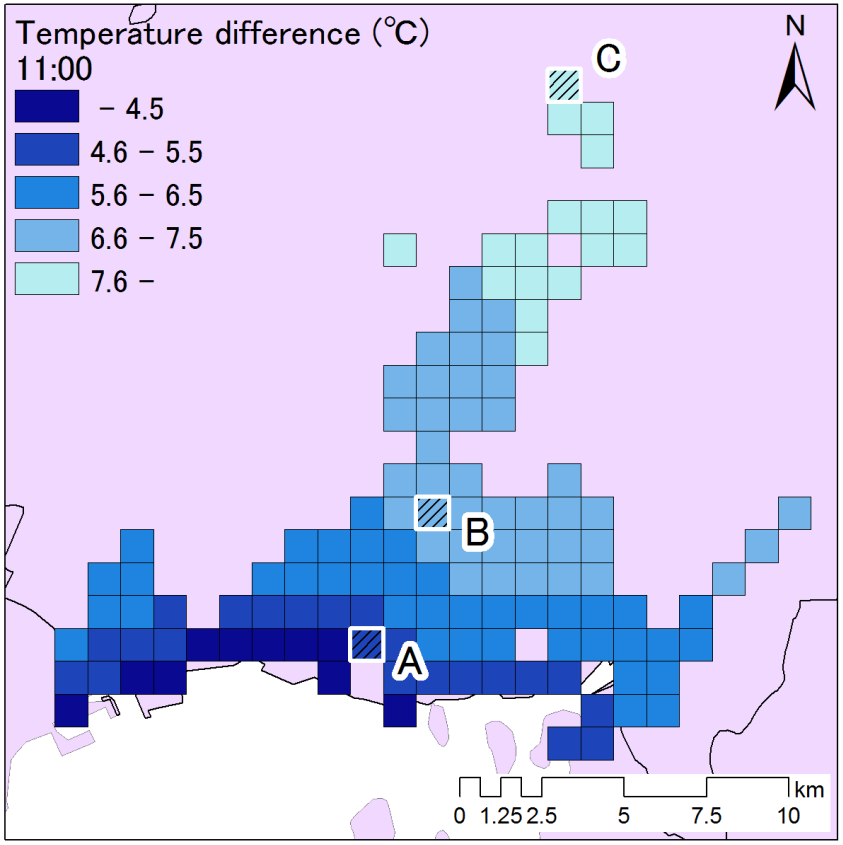
The spatial distribution pattern of sea breeze effect made from the numerical calculation is similar to the one which is made from the observed temperature.

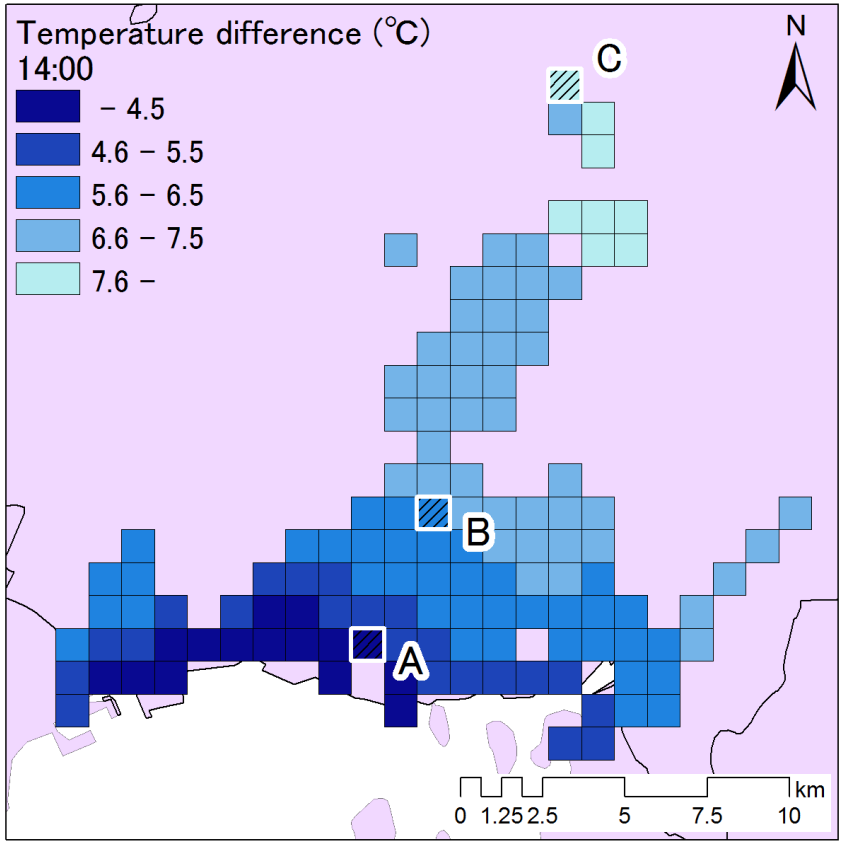




The difference of sensible heat advection by area

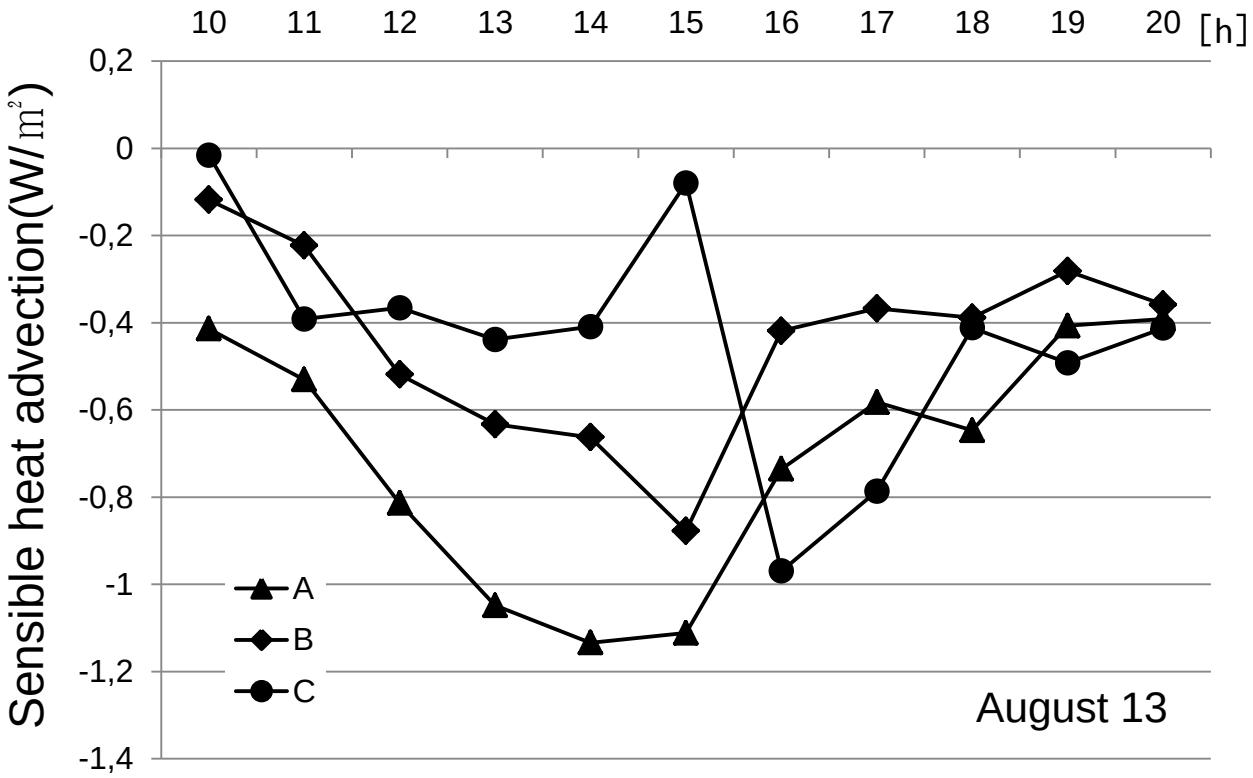
The hourly sensible heat advection is calculated on representative three meshes in Aug. 13.

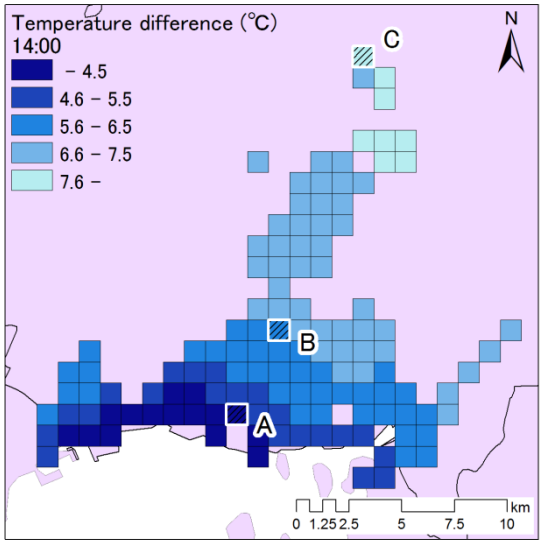




Discussion

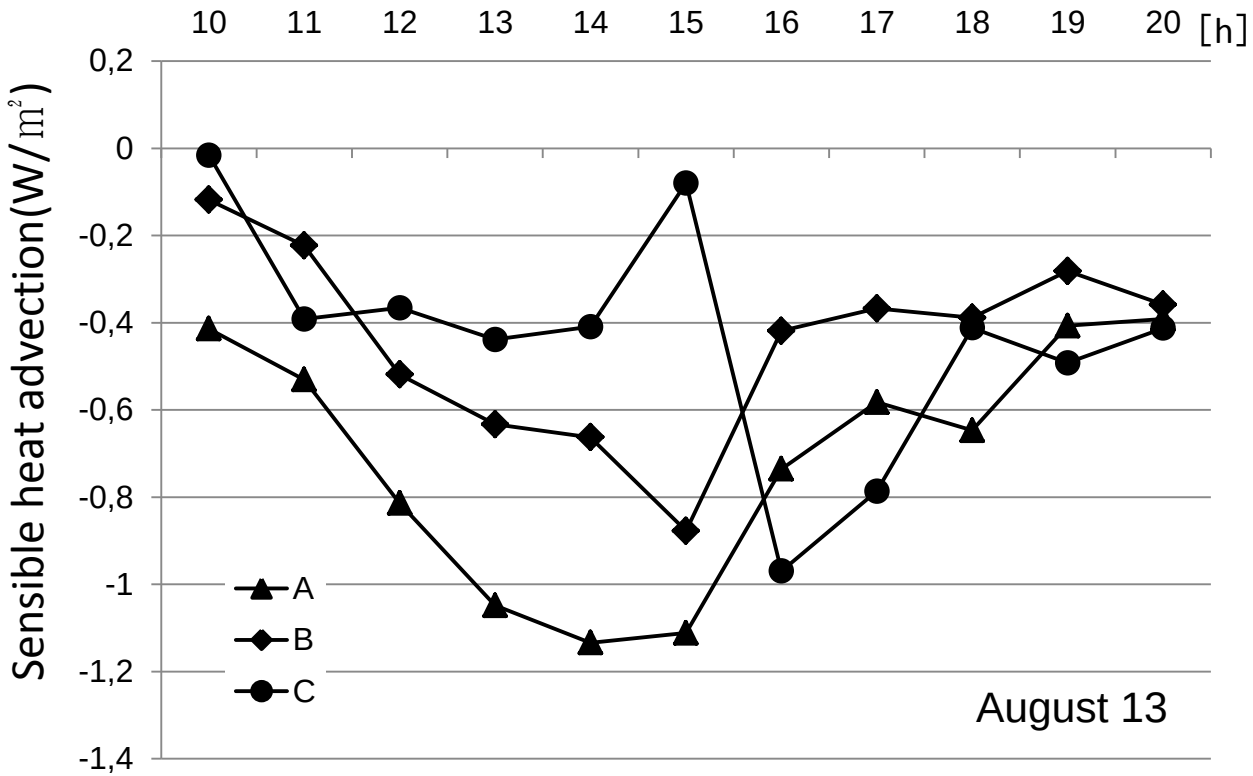
The absolute value of sensible heat advection
Mesh A: relatively larger in all time
Mesh B: large at 12:00 ,Mesh C: large at 16:00

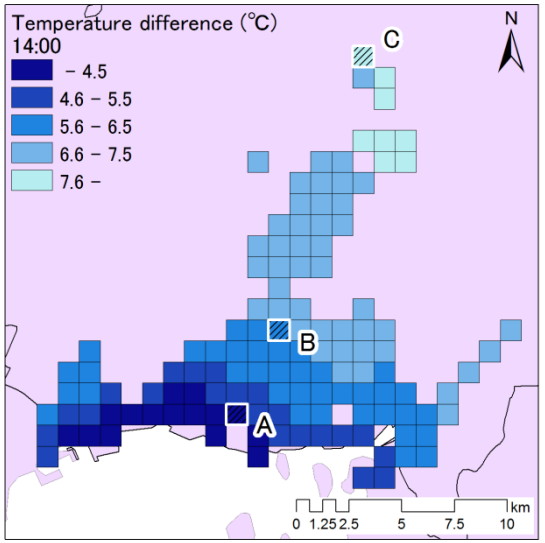




Discussion

According to these results, the temperature difference pattern between “the days that sea breeze blows” and “ the days that sea breeze doesn’t blow” is influenced by sea breeze.





Method

1. Understanding the sea breeze effect distribution using the observed temperature of 39 points.

2. Making the map of the sea breeze effect distribution using the meso-scale meteorological model.

3. Analyzing the relationship between the observed temperature and the local ventilation conditions.

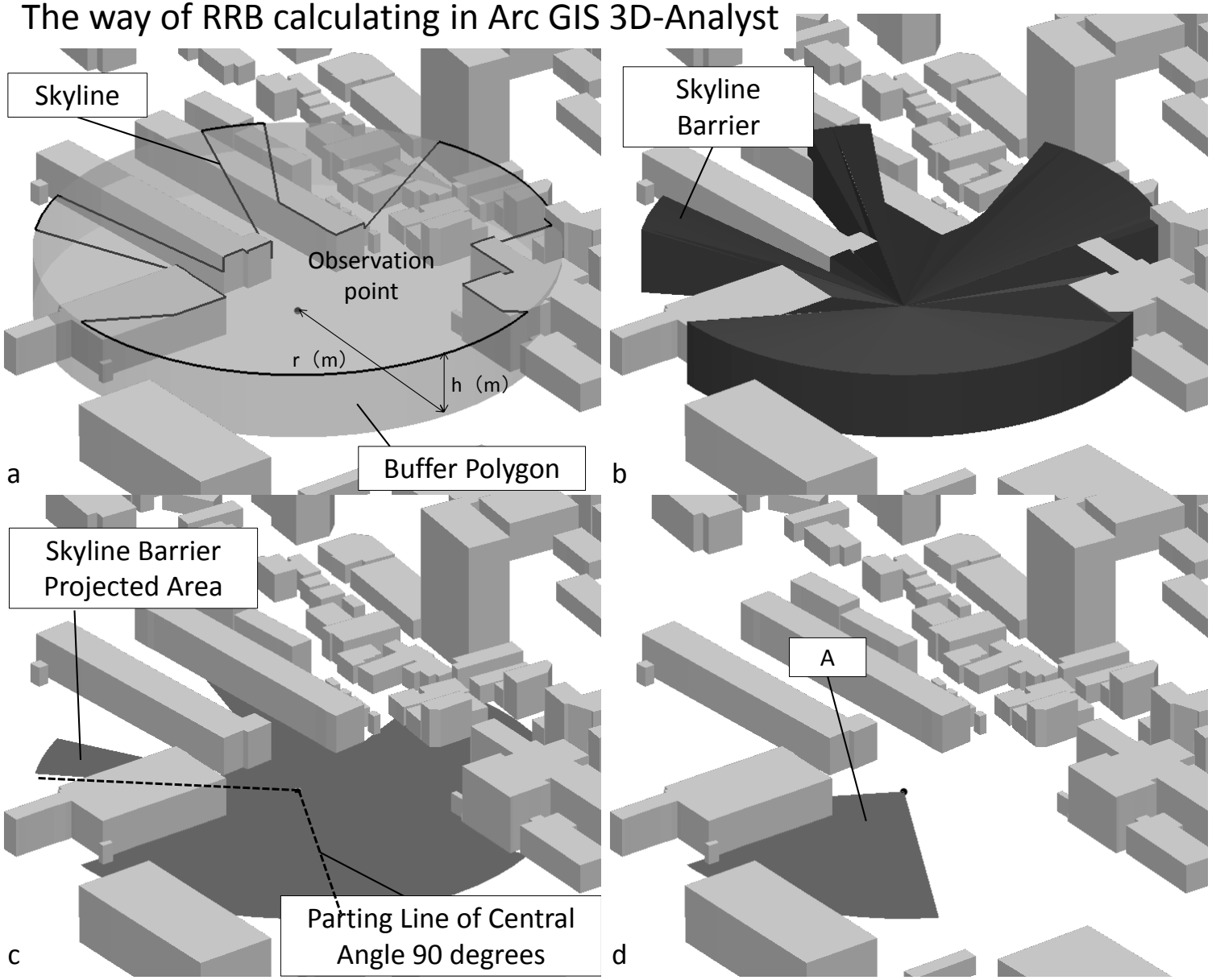
Introduction

It is considered that the temperature in each place is influenced by not only sea breeze effect that is regional factor but also surrounding ventilation condition that is local factor.

Analysis of the relationship between the observed temperature and the surrounding ventilation condition by using the rate of building blocking (RRB).

First, the RRB is calculated on all temperature observation points (39points).

The way of RRB calculating in Arc GIS 3D-Analyst



RRB_{ssw} =(X-A)/X×100

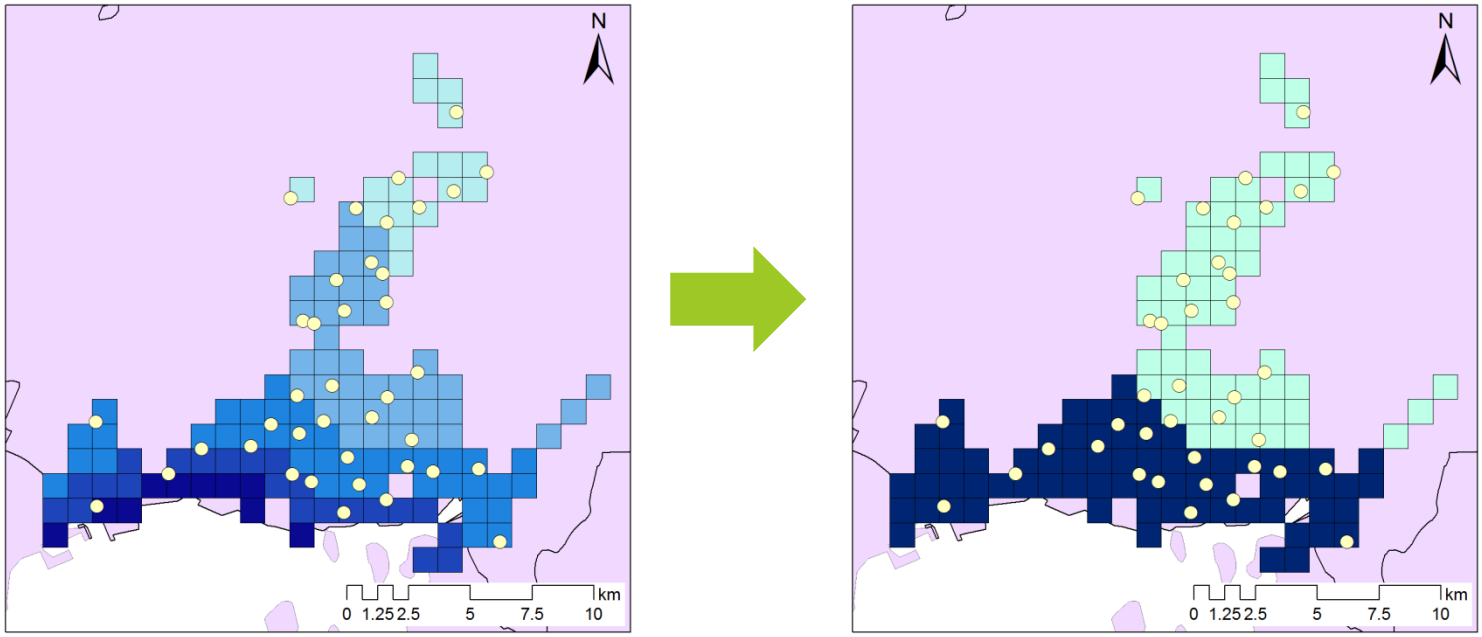
X: Area of sectorial polygon

Analysis

Next, the correlation coefficient between these RRB and average temperature at 14:00 for each zone are calculated.

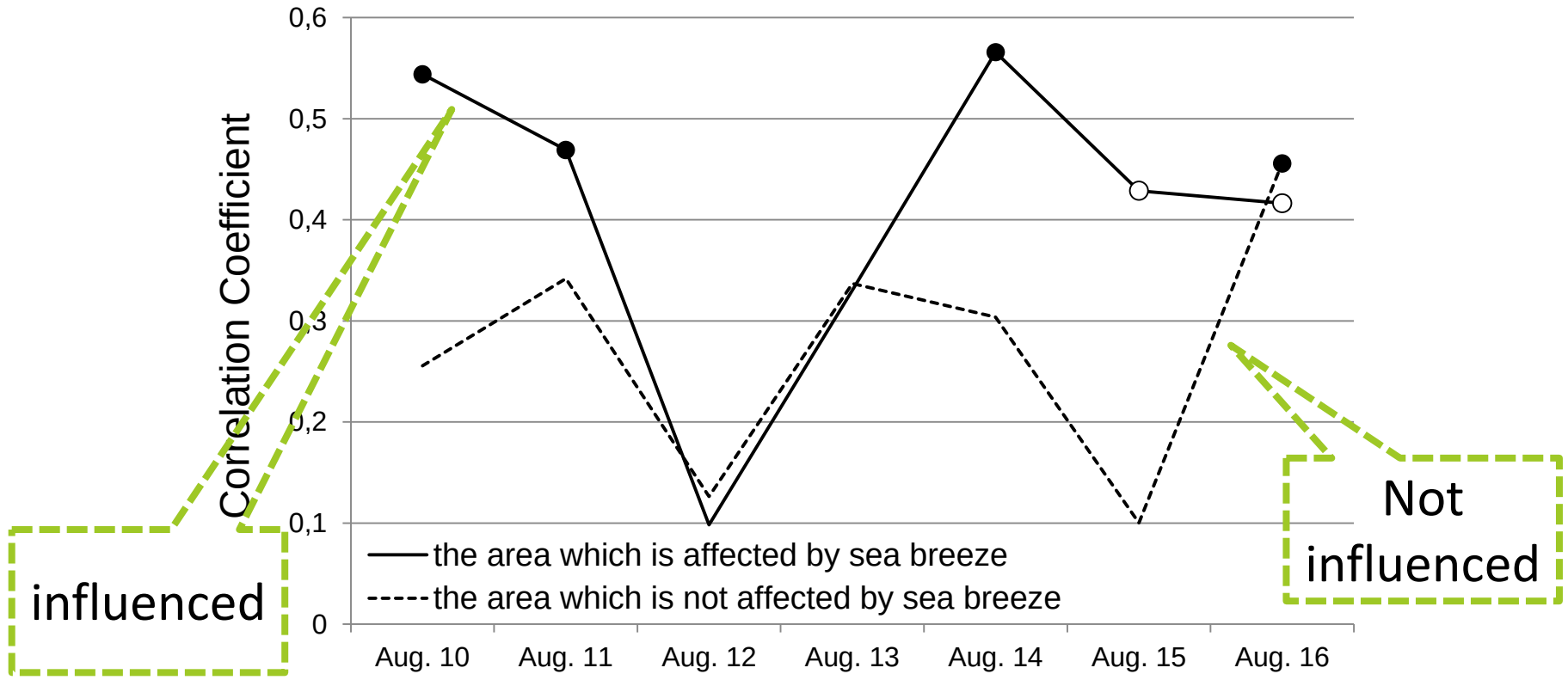
Each zone is integrated to following two zones because observation points are limited in number;

1) The area which is affected by sea breeze
2) The area which is not affected by sea breeze



Discussion

It is considered that the effect of surrounding ventilation condition is larger in the south area of plain.



●: statistically significant at the 5%、○: statistically significant at the 10%

Summary

From method 1,

The daytime temperature distribution is related with sea breeze.

From method 2,

The map of the sea breeze effect distribution is made using the meso-scale meteorological model.

From method 3,

The effect of surrounding ventilation condition is larger in the south area of plain.