Impact of an Urban Land Surface Scheme on Local Climate Simulation for the Tokyo metropolitan area

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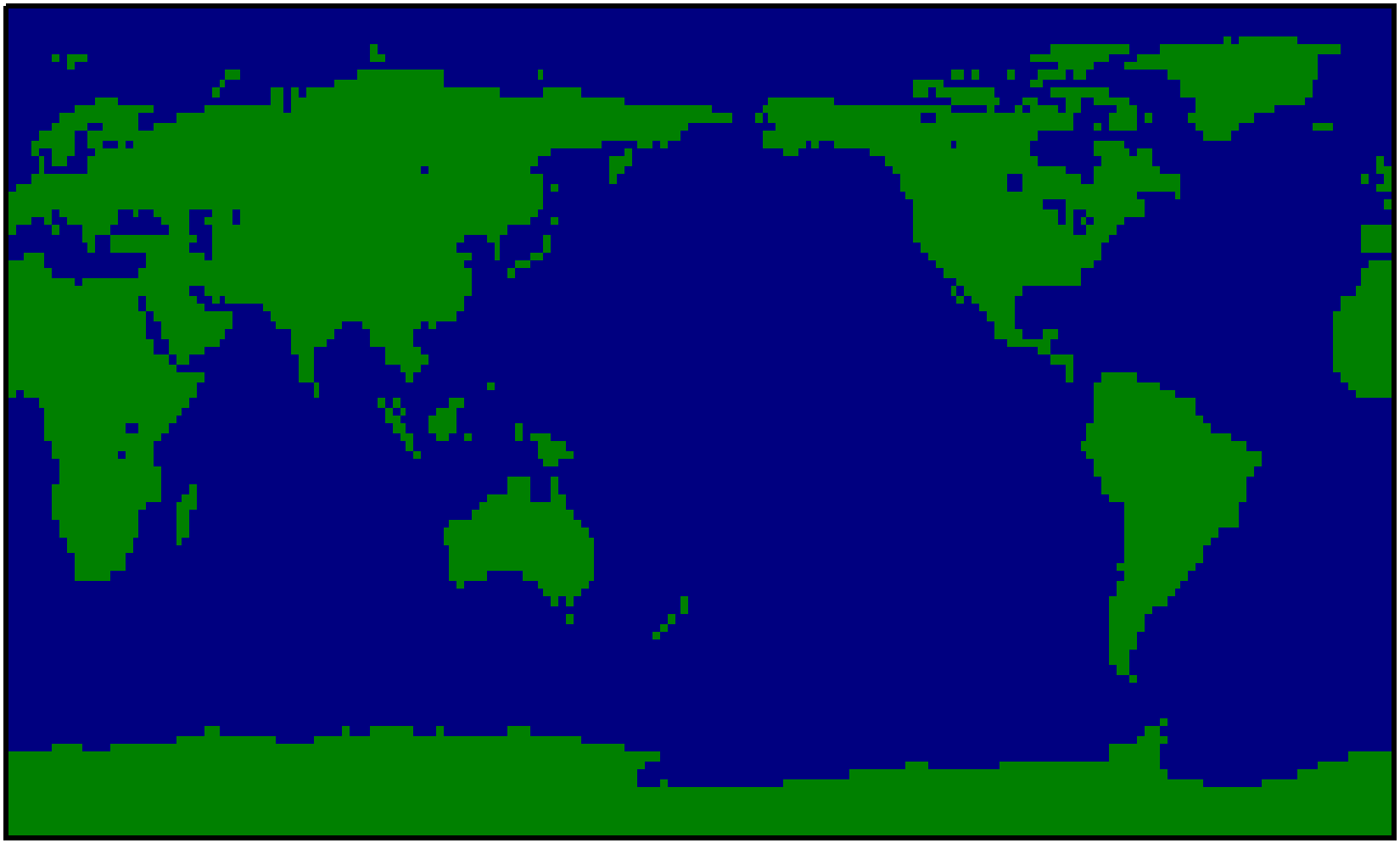
This research is supported by SOUSEI program of MEXT, Japan.

Introduction

- The land surfaces take an important role to provide dynamical and thermal energy to the atmosphere above.
- Sophisticated vegetation scheme has been introduced to the climate models
- The Non-Hydrostatic Regional Climate Model (NHRCM) of the Japan Meteorological Agency has been applying a vegetation scheme MJ-SiB (Ohizumi and Hosaka 2000) based on the Simple Biosphere model (SiB; Sellers et al. 1986).
- However, non-vegetation but urbanized grids became obvious as the resolution of the model higher up to several km.

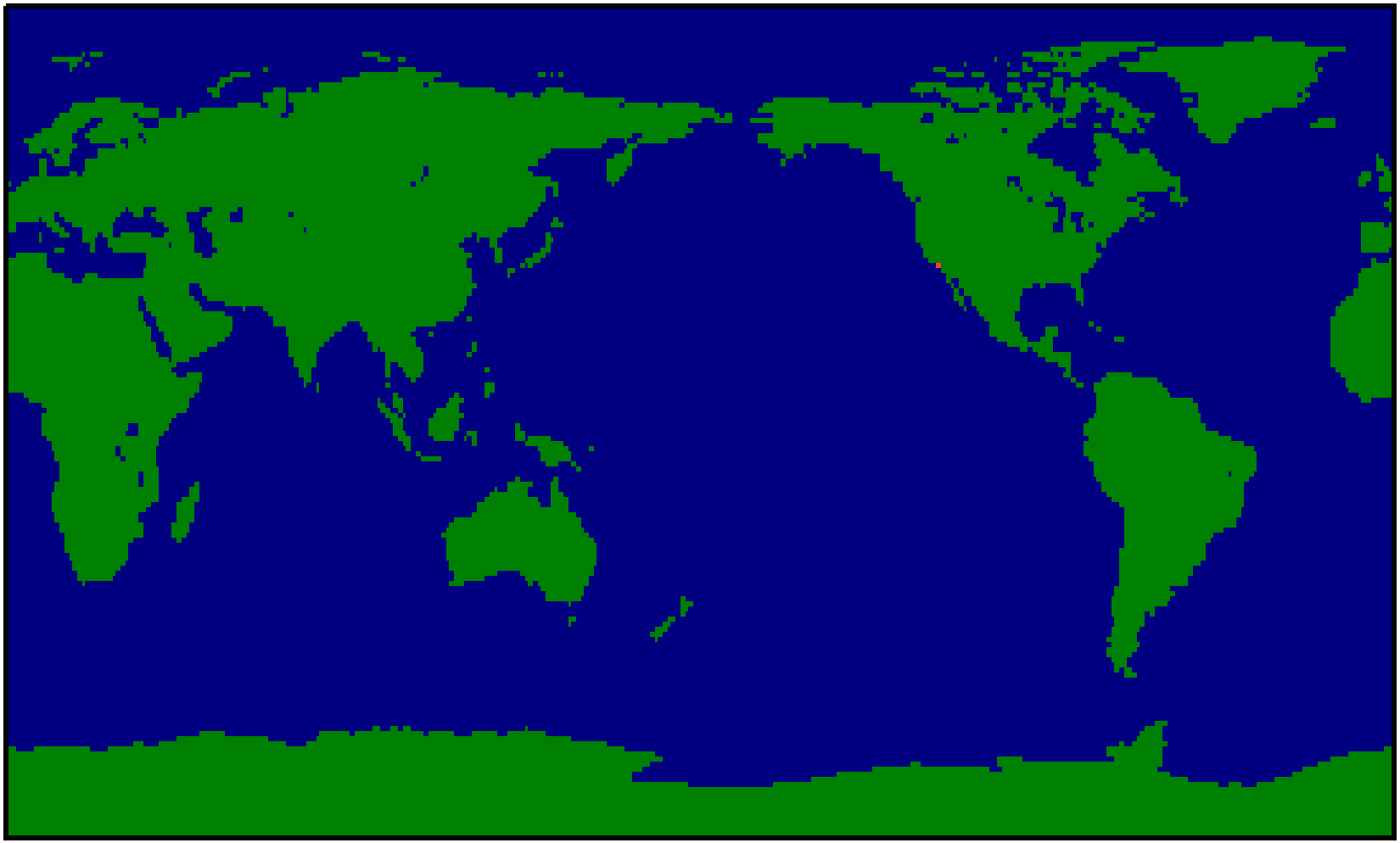
TL95 ($\Delta \simeq 200$km)

Land Urban Sea (Water)



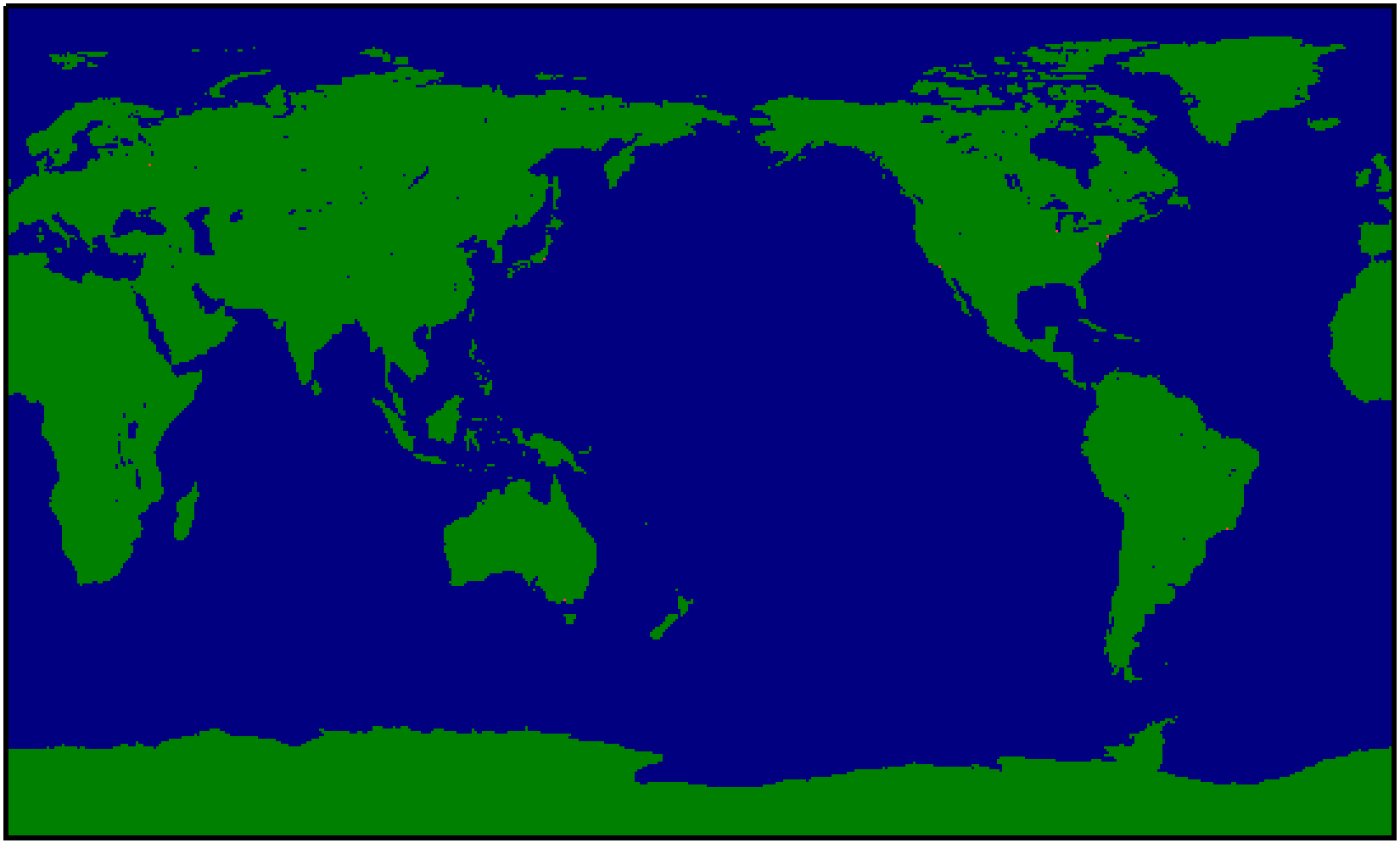
TL159 ($\Delta \simeq 120$km)

Land Urban Sea (Water)



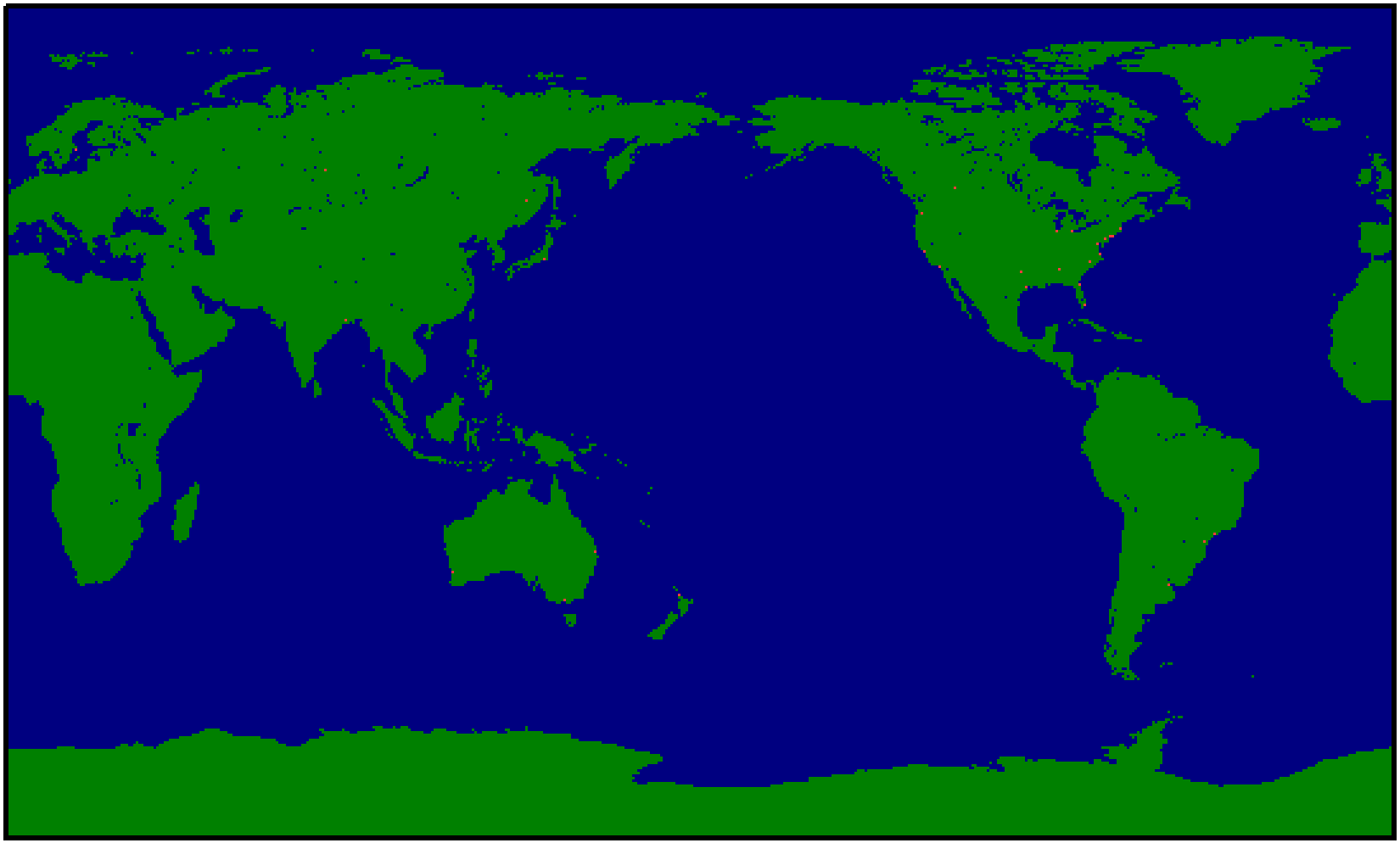
TL319 ($\Delta \simeq$ 60km)

Land Urban Sea (Water)



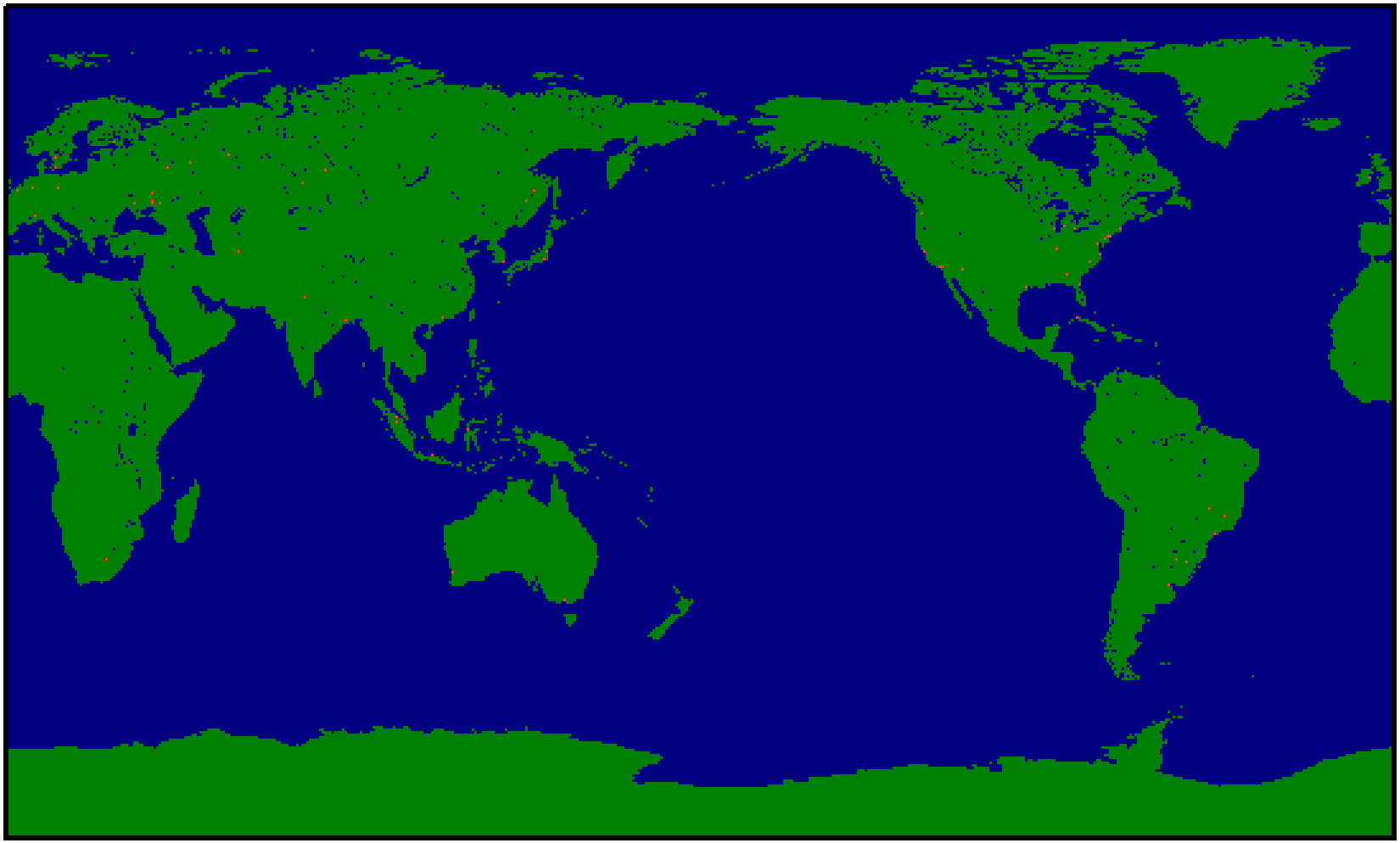
TL959 ($\Delta \simeq$ 20km)

Land Urban Sea (Water)

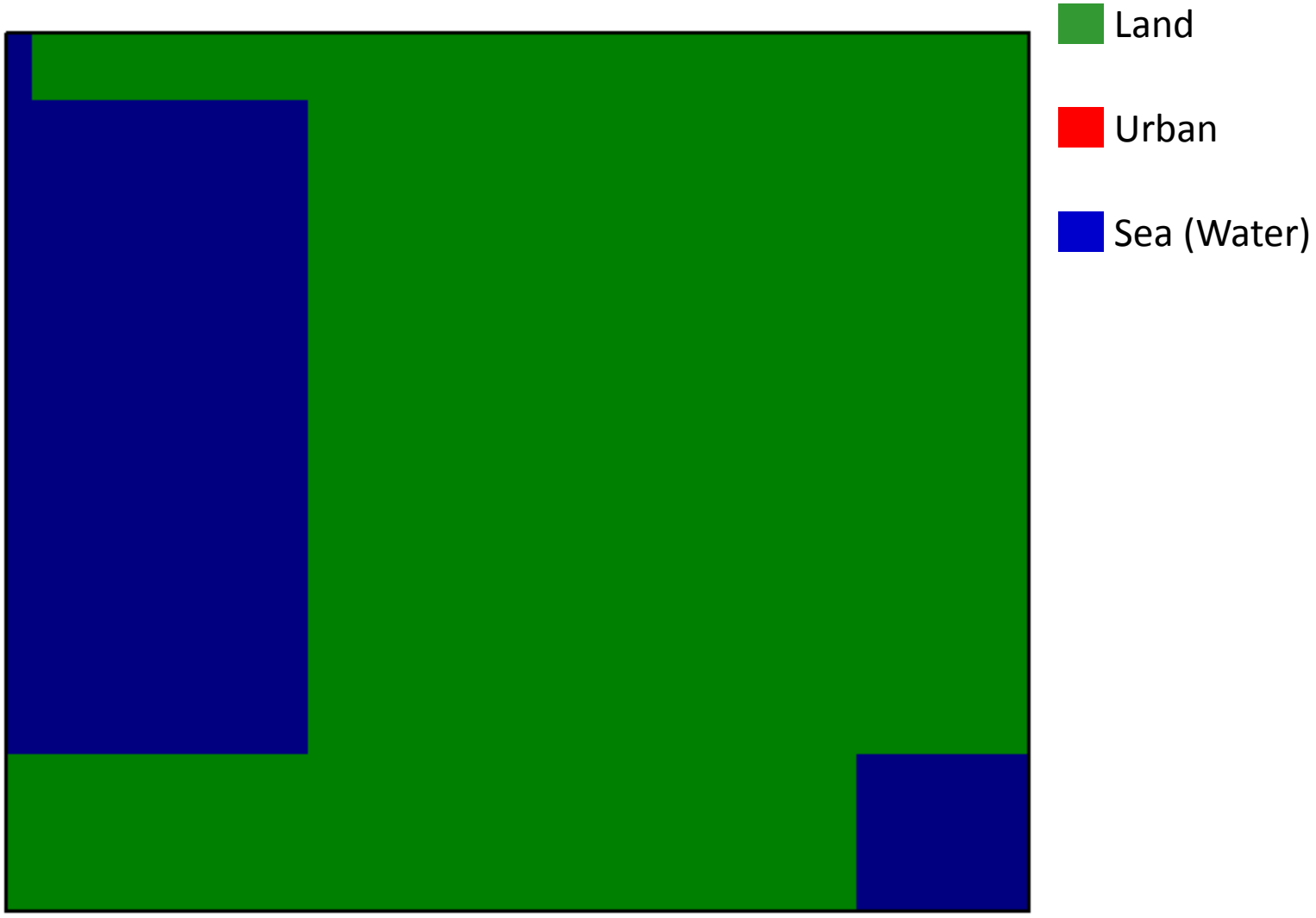


TL3839 ($\Delta \simeq$ 5km)

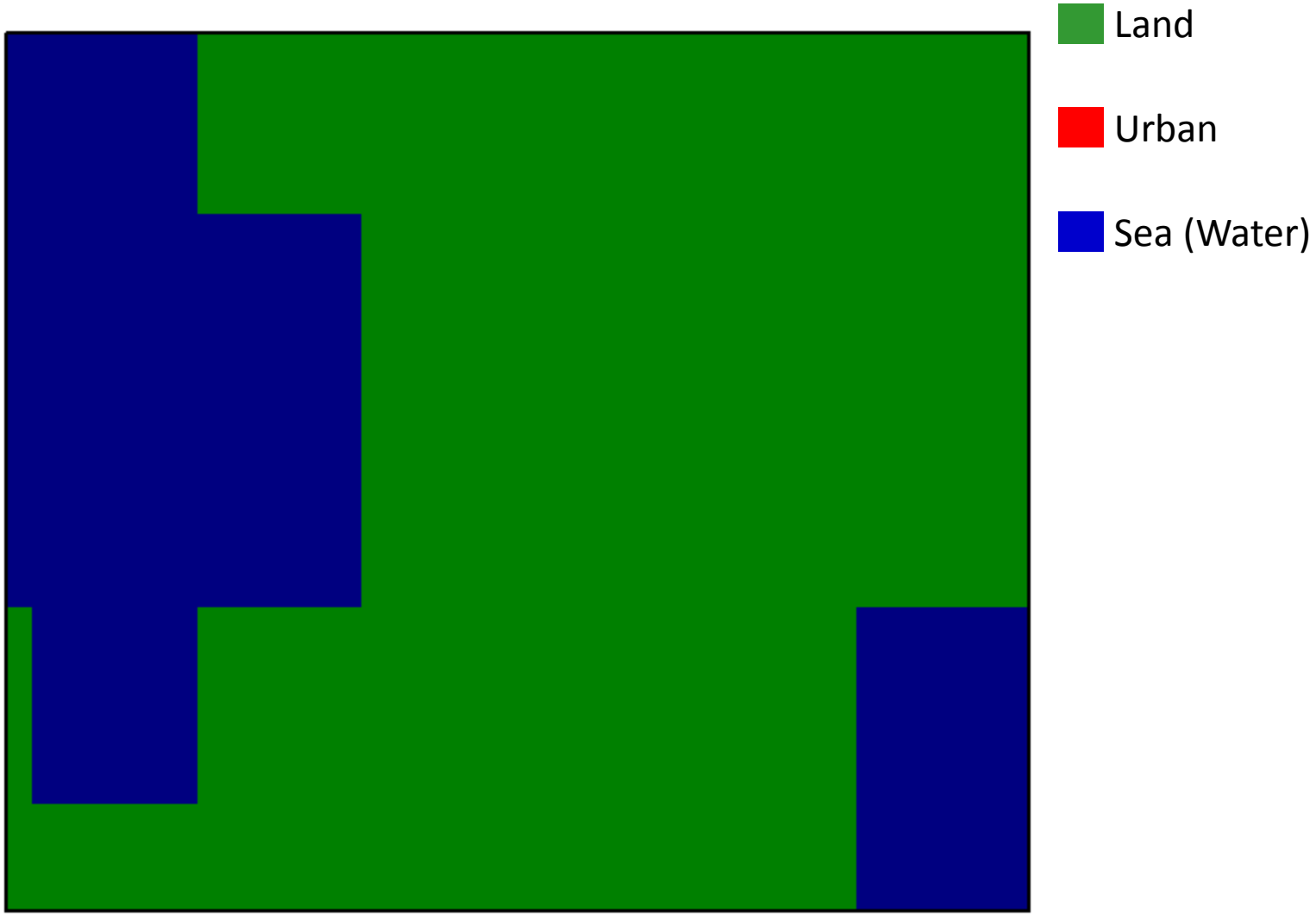
Land Urban Sea (Water)



TL95 ($\Delta \simeq 200$km)



TL159 ($\Delta \simeq 120$km)



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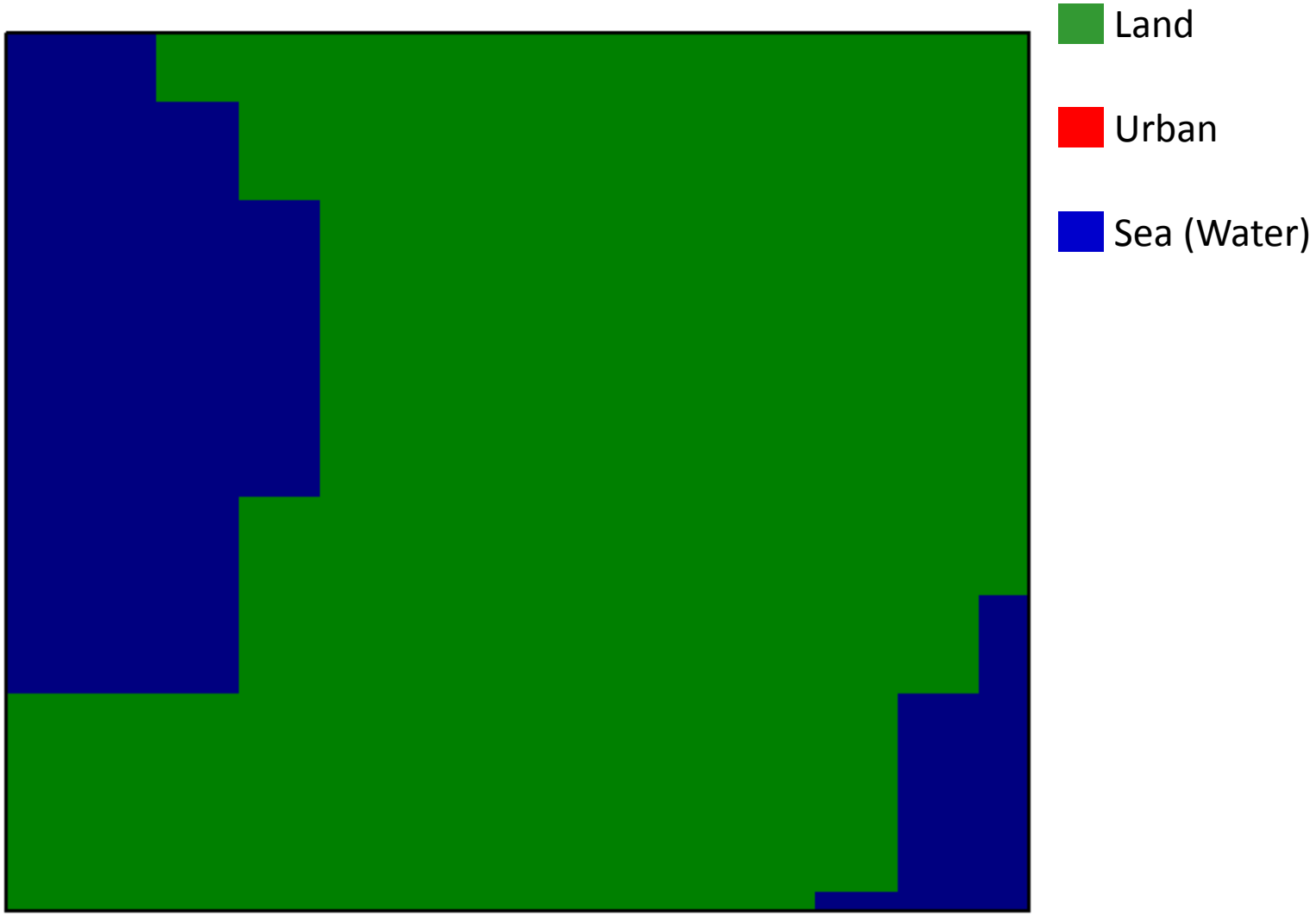
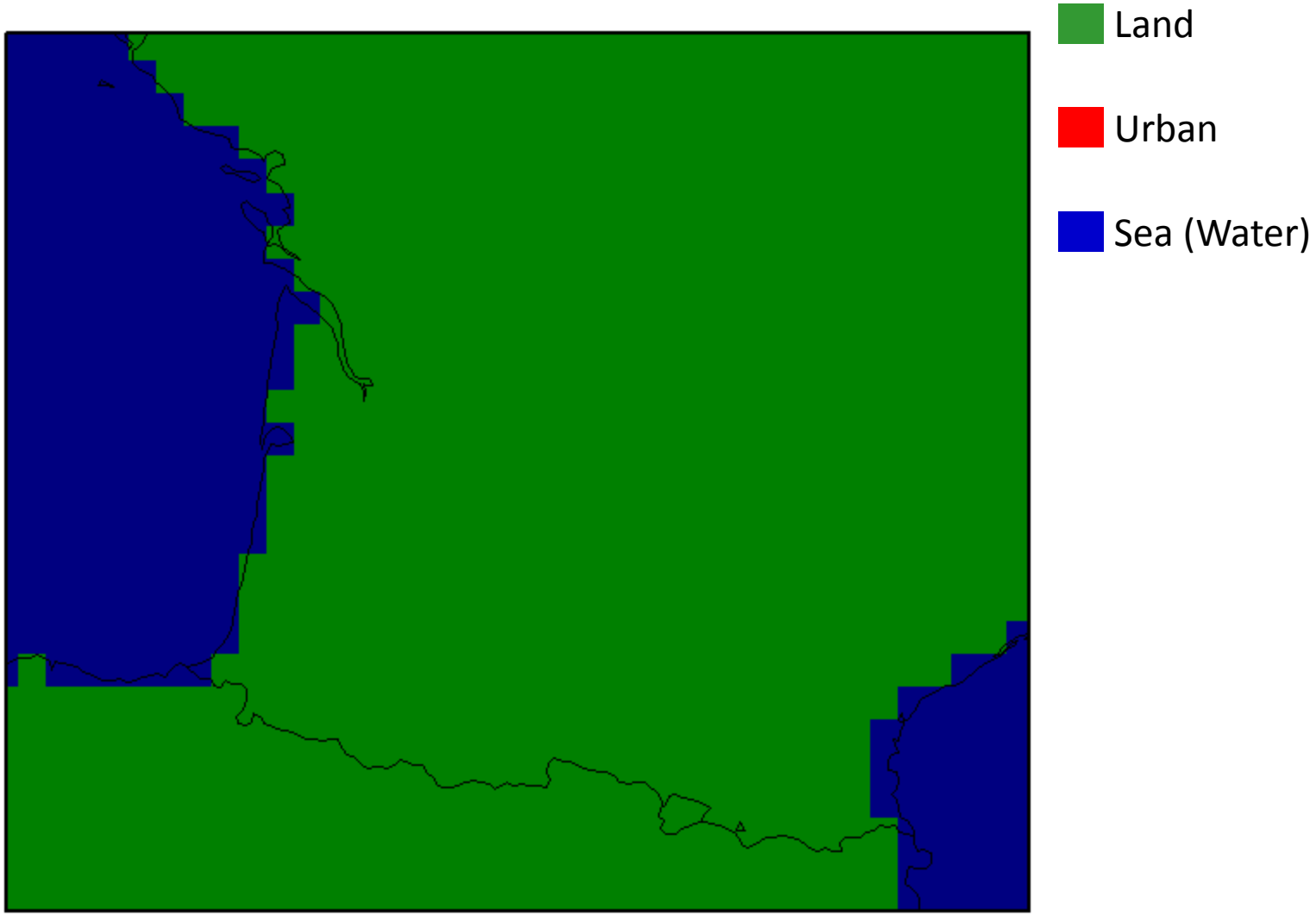
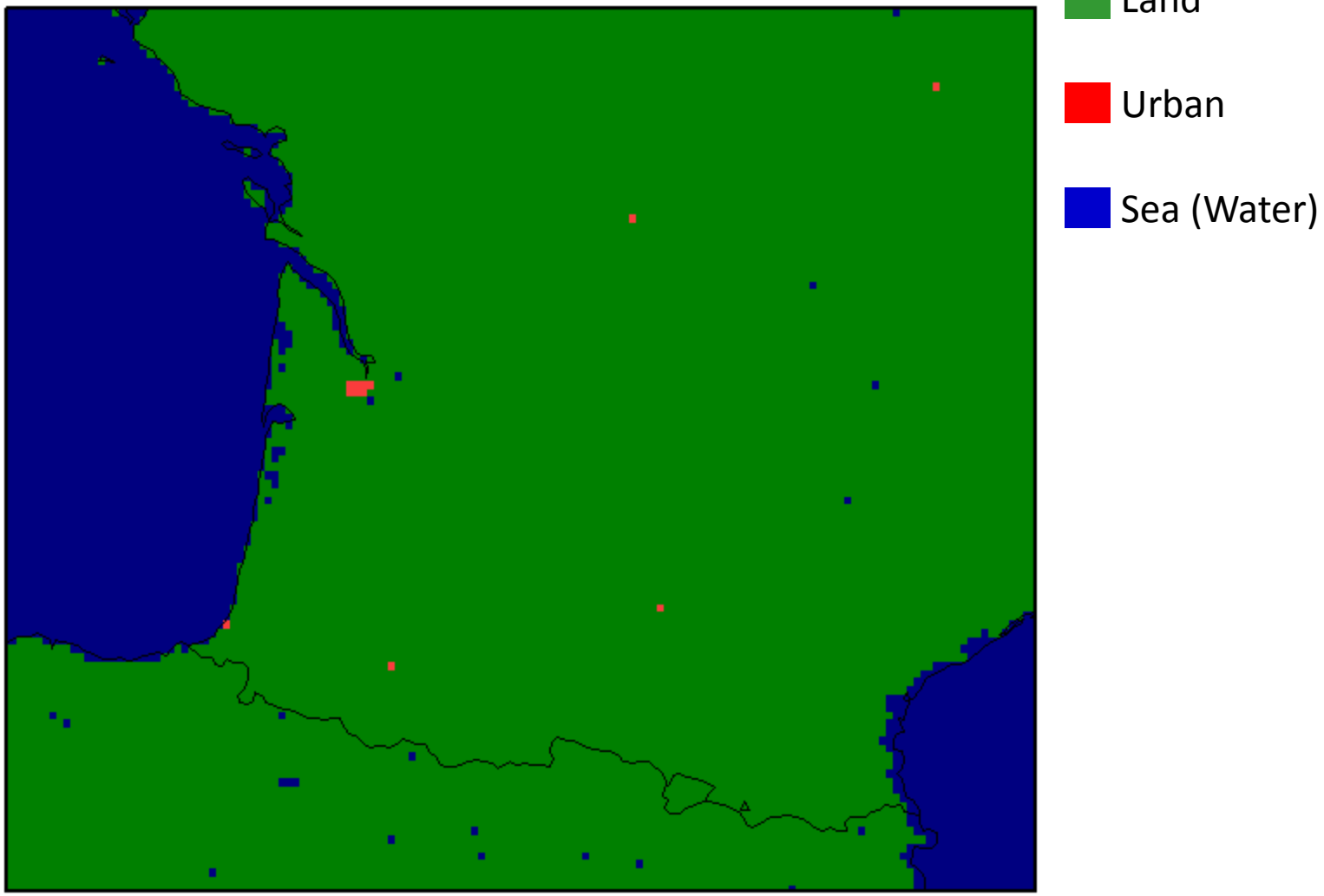


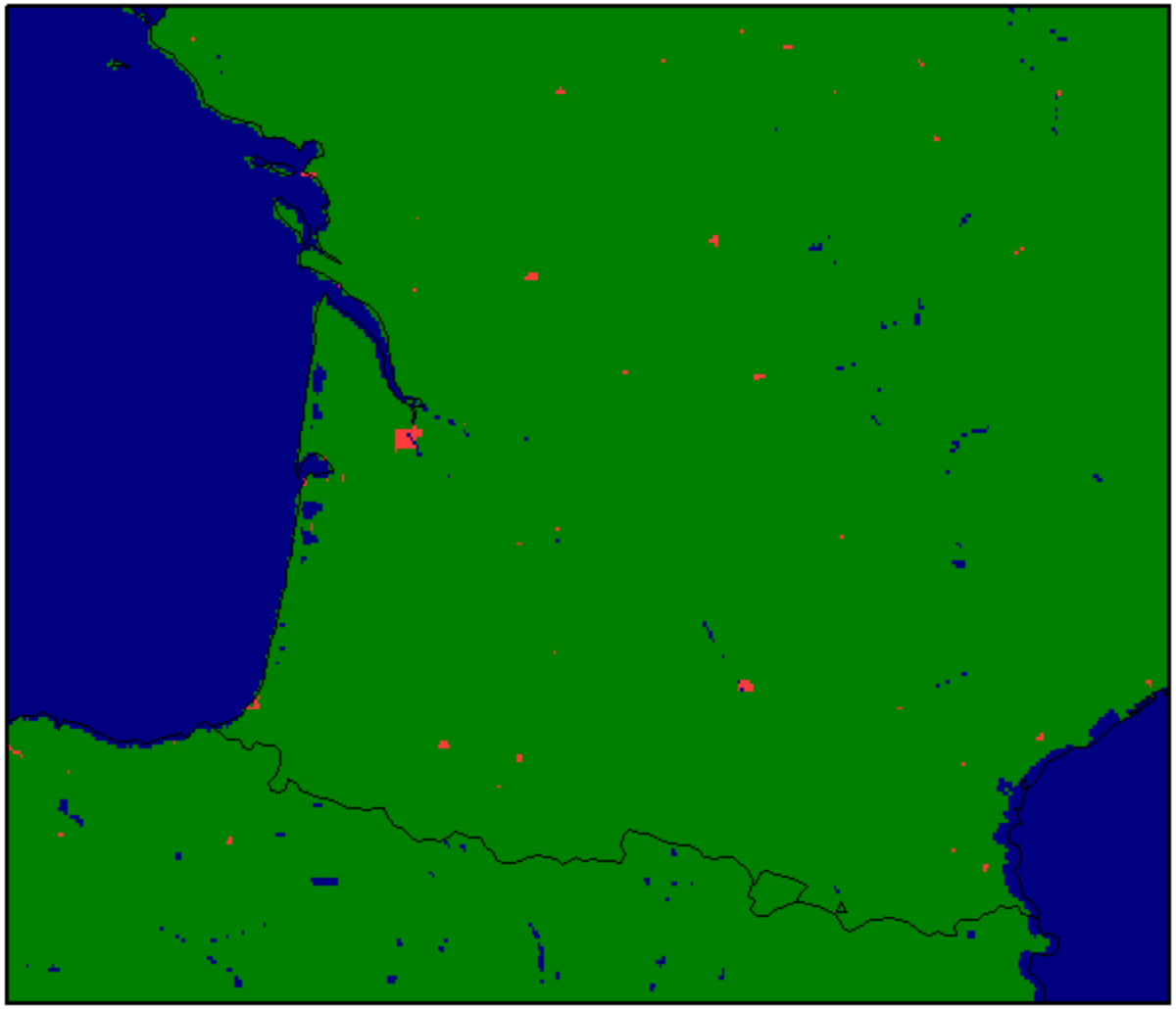
TL959 ($\Delta \simeq 20$km)



TL3839/NHRCM05
($\Delta \simeq$ 5km)

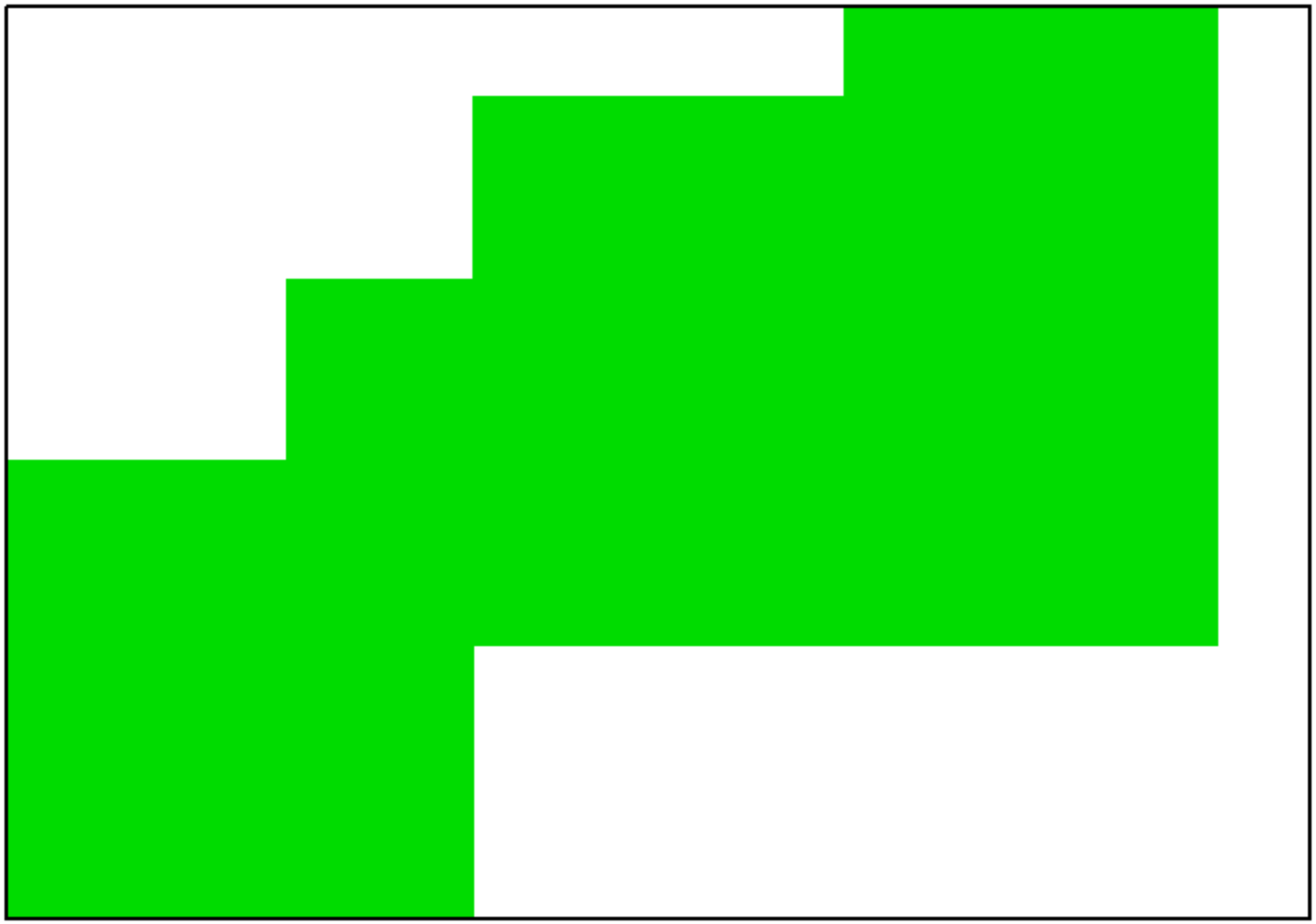


TL9599/NHRCM02
($\Delta \simeq$ 2km)

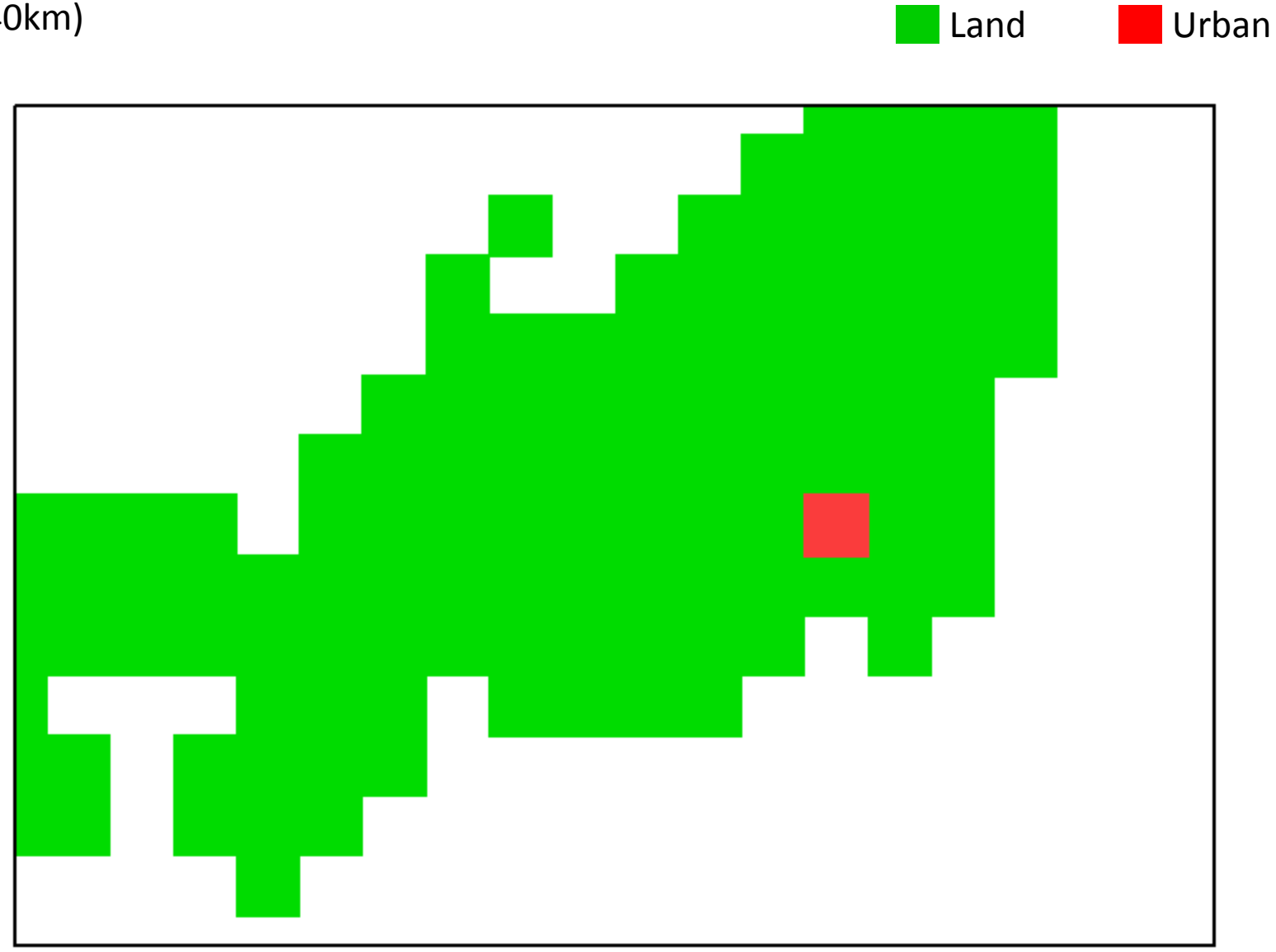


($\Delta \simeq$ 100km)

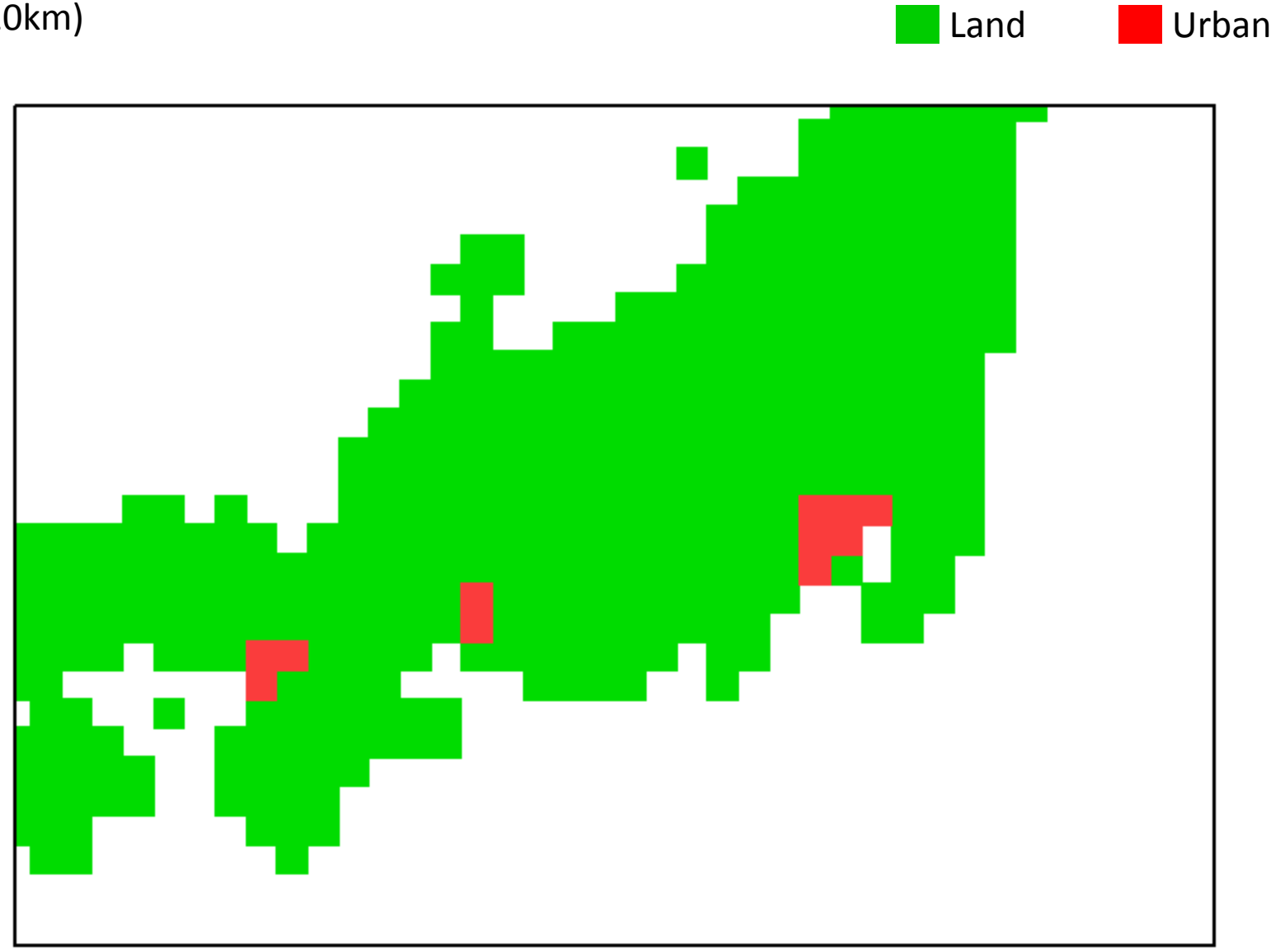
Land Urban



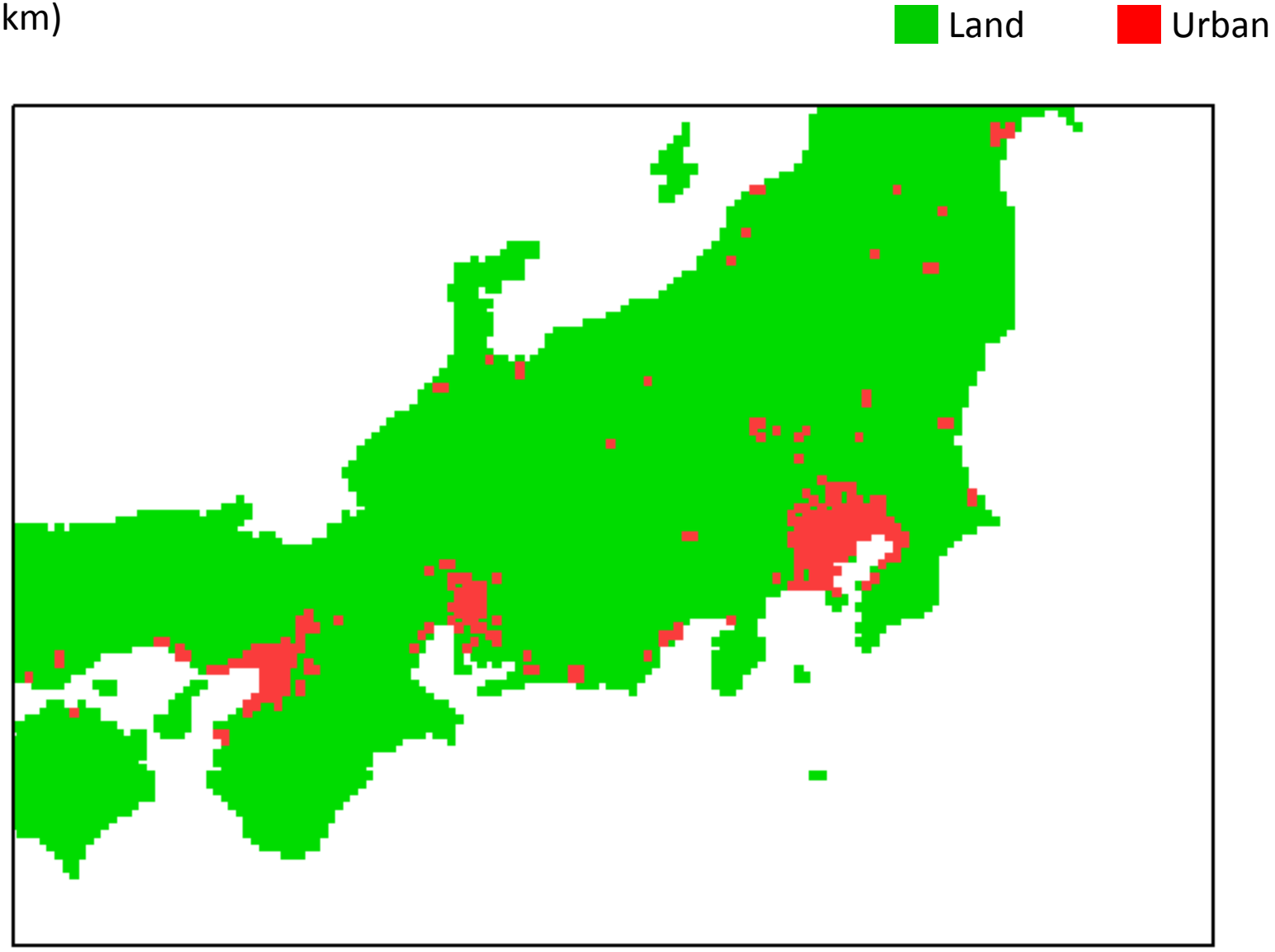
($\Delta \simeq$ 40km)



($\Delta \simeq$ 20km)

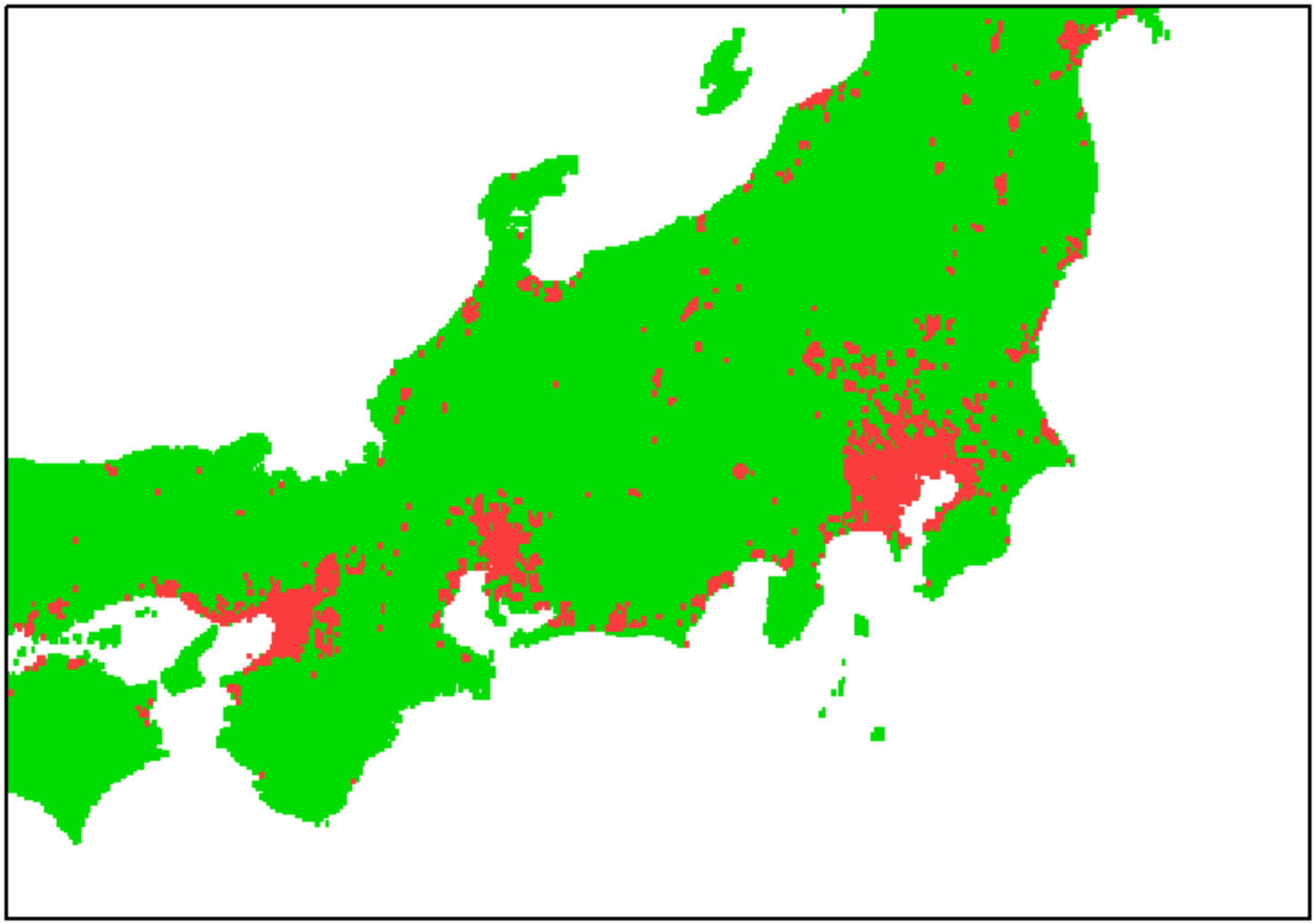


($\Delta \simeq$ 5km)



($\Delta \simeq$ 2km)

Land Urban



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- However, non-vegetation but urbanized grids became obvious as the resolution of the model higher up to several km.
- MJ-SiB treats such urban surfaces as dried bare ground .

→ Reproducibility was not sufficient (Sasaki et al. 2008)

Introduction

- We introduced our urban canopy scheme called SPUC (Square Prism Urban Canopy; Aoyagi and Seino 2011) to the NHRCM.

- We checked impacts of the scheme on present climate reproduction.

Experimental Settings

Domain : Kanto area including Tokyo metropolis

Term : Sep. 2001 – Aug. 2006 (5 years)

Initial & Bound. : RANAL (20km-JMA's Regional Analysis)

Dynamical Downscaling:

RANAL20km → NHRCM10km → NHRCM4km

We operated NHRCM10km before executing NHRCM4km in order to grow up water substances in NHRCMs, because RANAL20km holds only the information of specific humidity.

- We switched the land surface schemes (MJ-SiB / SPUC) in NHRCM4km.

Experimental Settings

NHRCM_SiB :

Using the MJ-SiB scheme in all land grids

(Express urban areas as dried bare land)

NHRCM_SPUC :

Apply the SPUC scheme to urban grids, the MJ-SiB scheme to other grids

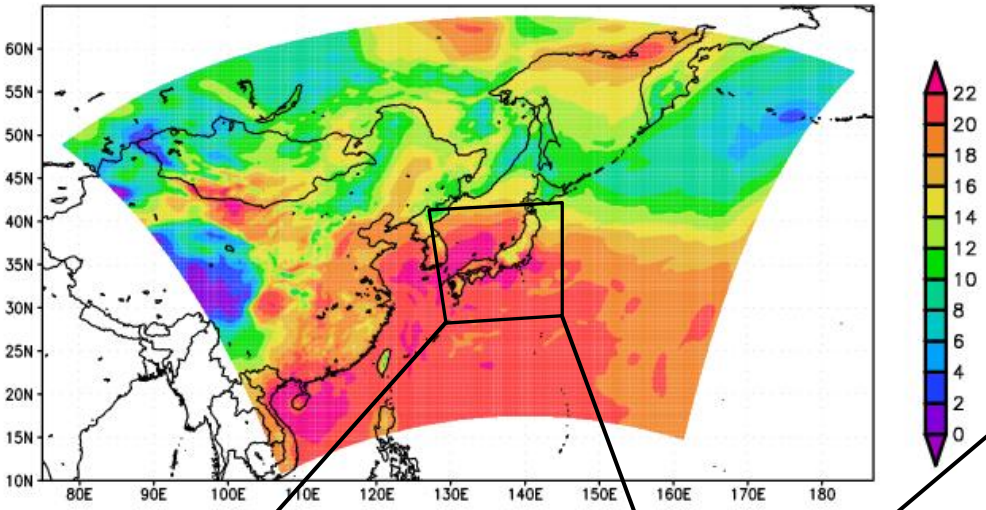
Urban grids:

Over 50 % of building area, road area, and other bare urban area in the grids. Estimated by using the National Digital Land Information database of Japan.

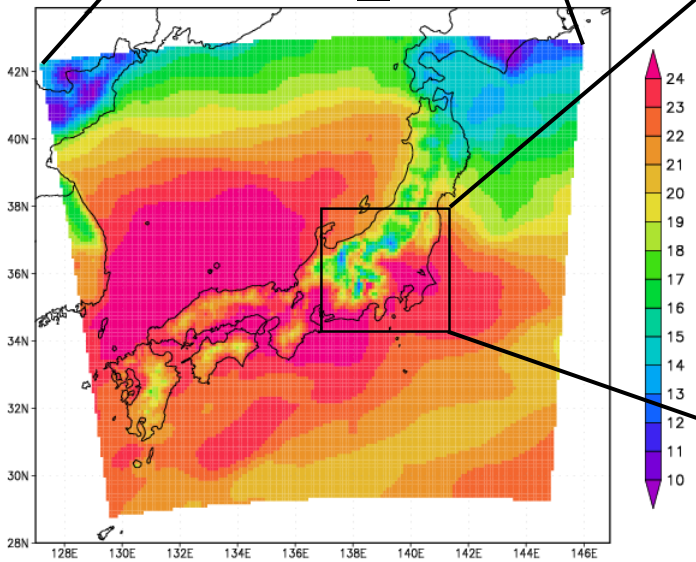
All the settings except for the land surface scheme are the same in the two experiments.

Experimental Settings

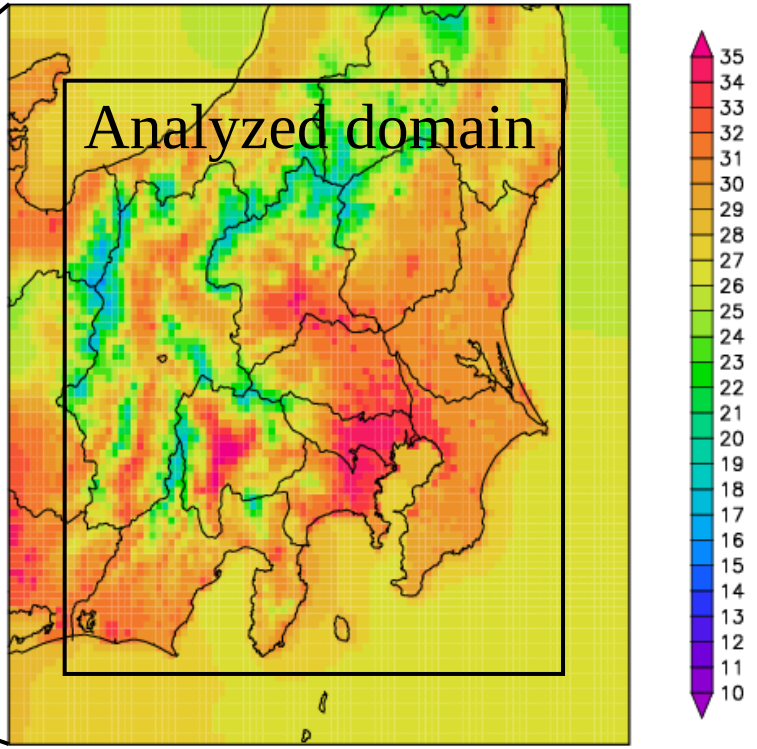
RANAL_20km



NHRCM_10km

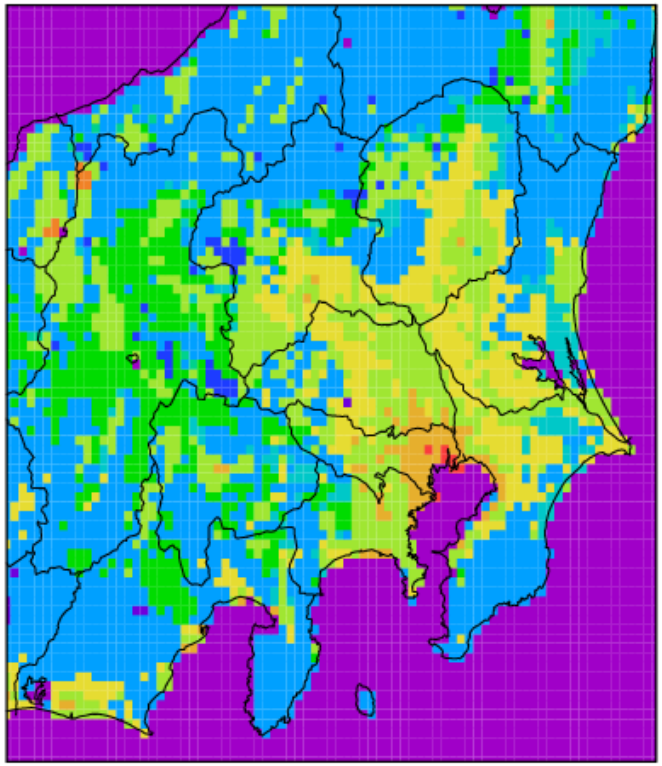


NHRCM_4km

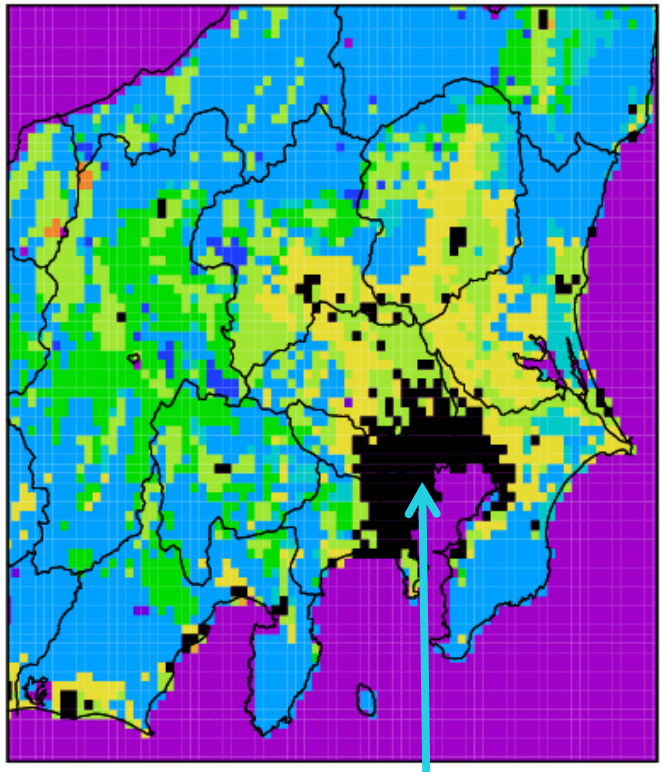


Experimental Settings

NHRCM_SiB



NHRCM_SPUC



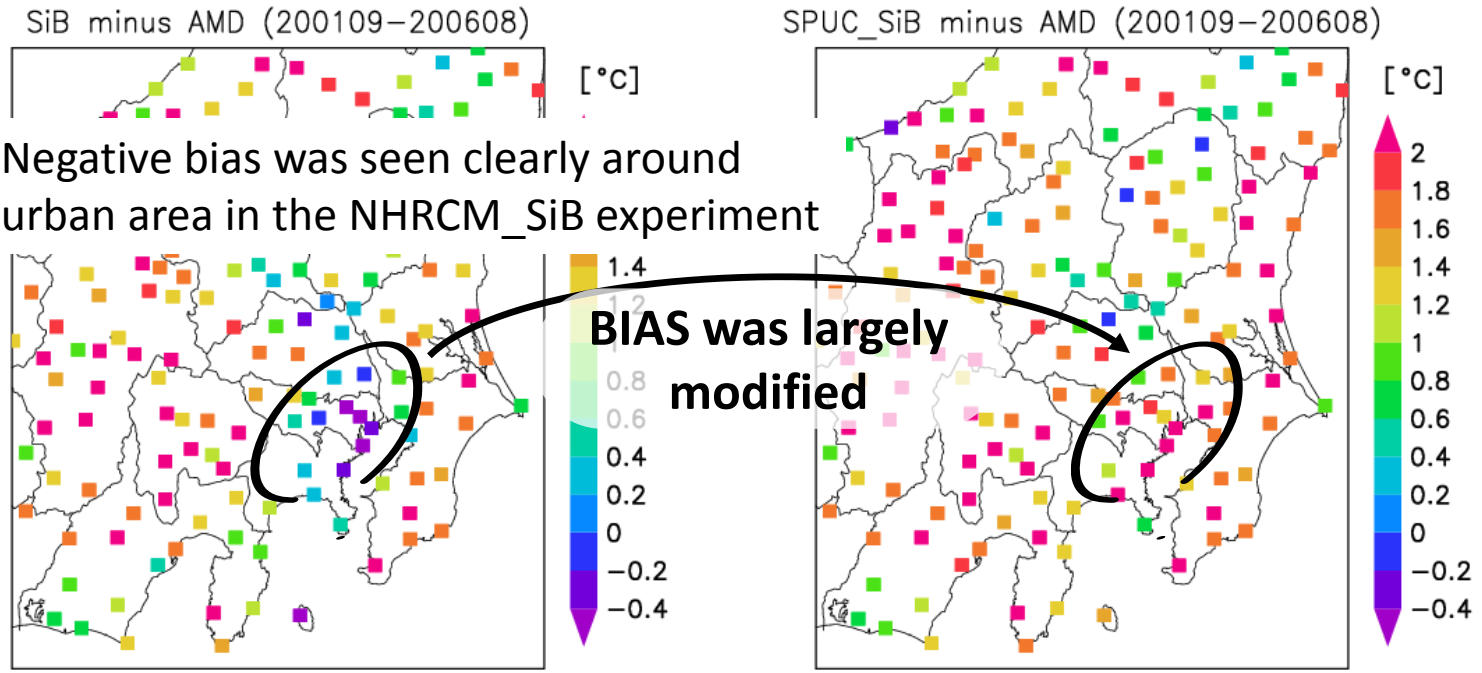
Apply the SPUC scheme to urban grids
(other grids remain the same (MJ-SiB))

Result (Surface Air Temperature)

Estimation of the reproduction of 5year-mean surface air temperature compared with the observation

NHRCM_SiB

NHRCM_SPUC



BIAS	1.30 ℃	→	1.55 ℃	got worse
Corr. Coeff.	0.73	→	0.86	improved

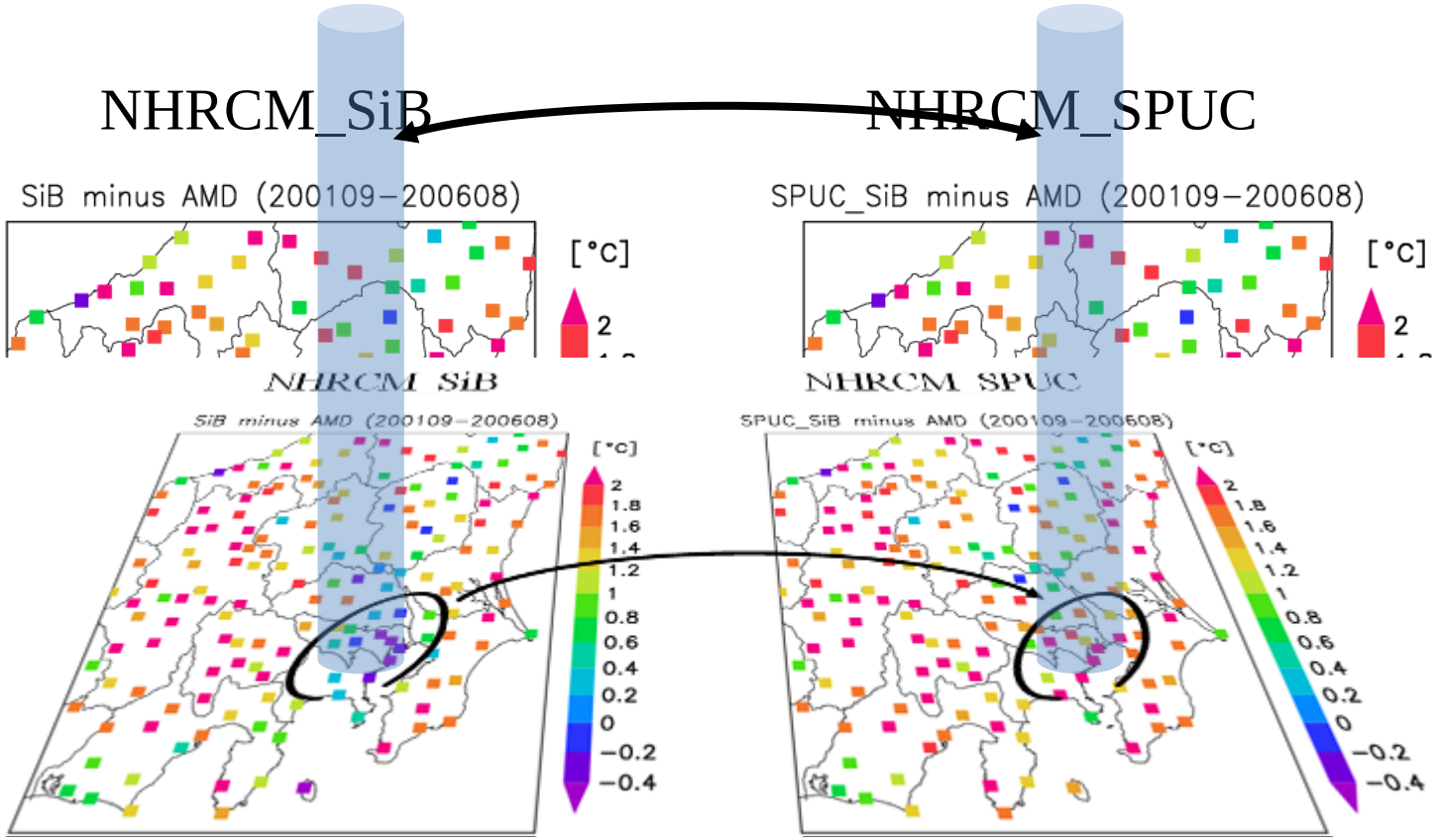
Result (Surface Air Temperature)

- 5year-mean surface air temperature :
  - Negative bias was seen clearly around urban area in the NHRCM_SiB experiment
  - The bias changed to be positive in the NHRCM_SPUC
  - Whole bias averaged over the domain was got worse from 1.30 ℃ (NHRCM_SiB) to 1.55℃ (NHRCM_SPUC)
  - Spatial correlation between reproduced and observed temperature over the domain was improved from 0.73 (NHRCM_SiB) to 0.86 (NHRCM_SPUC)

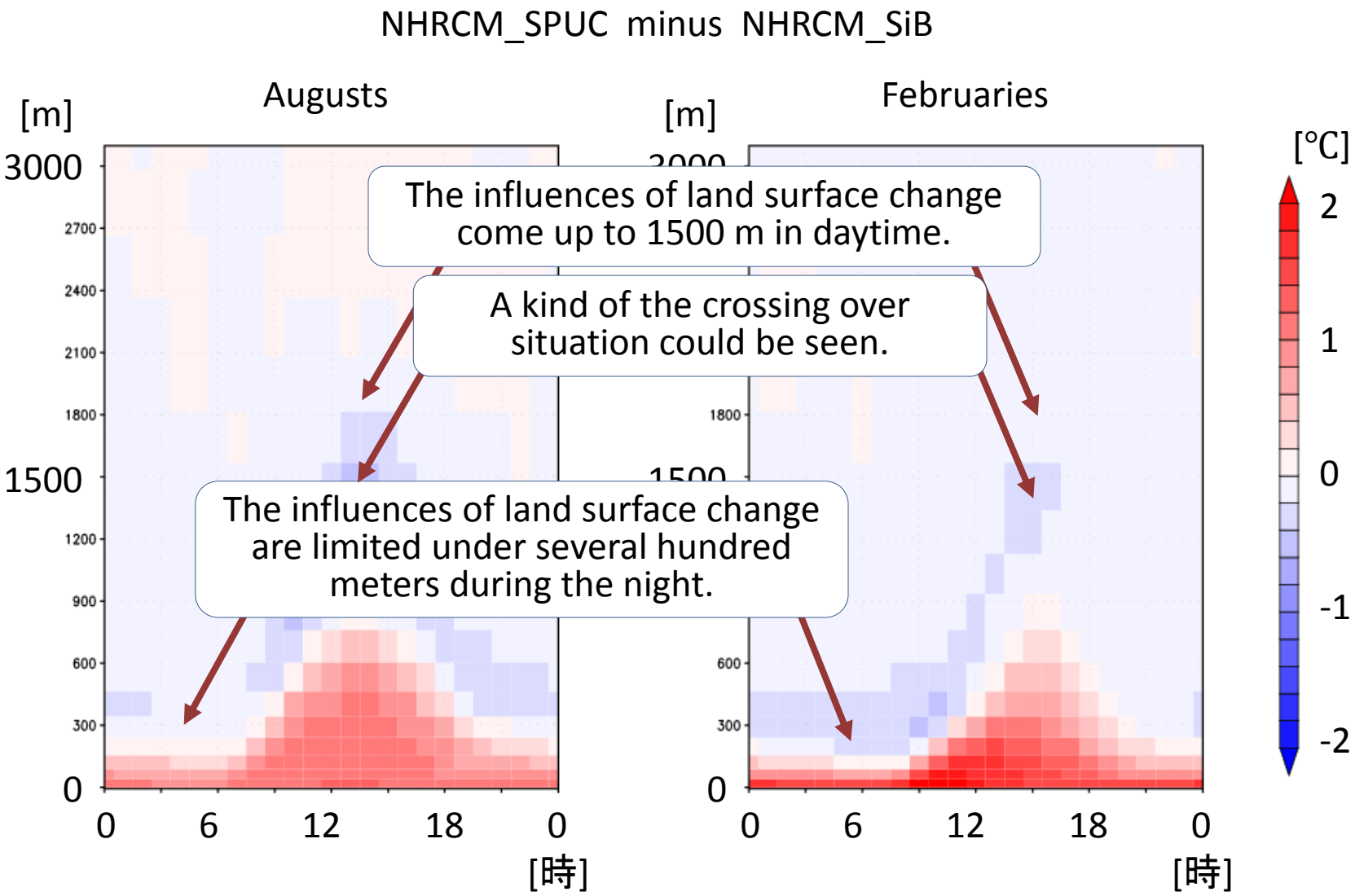
    ← The better reproduction of the temperature's horizontal distribution must result in the better reproduction of local circulations through the better reproduction of barometric gradient.

Result (Difference of monthly potential temperature profile over urban grids)

To figure out how high the effect of land surface modification can reach.



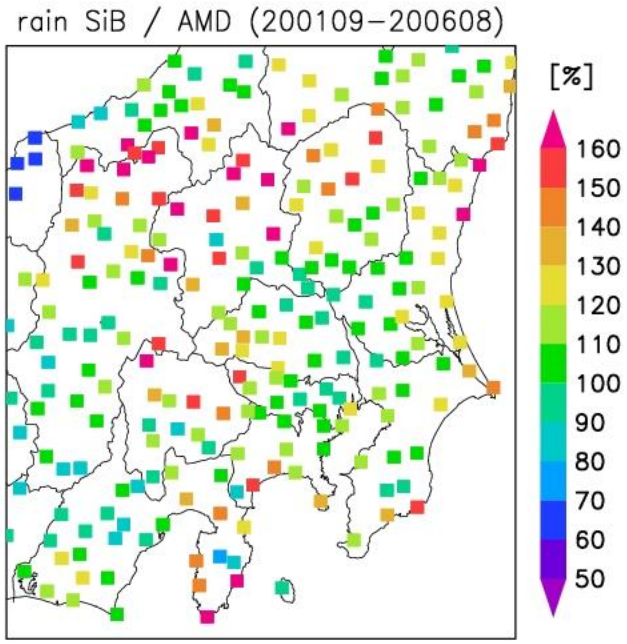
Result (Difference of monthly potential temperature profile over urban grids)



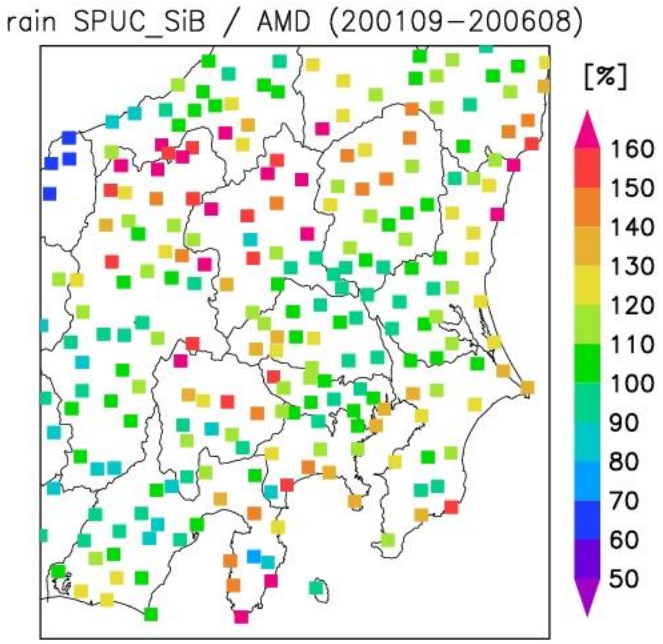
Result (Precipitation)

- Ratio of the 5-year total amount of precipitation towards observation

NHRCM_SiB



NHRCM_SPUC



Precip. Rate 119 % → 119 %

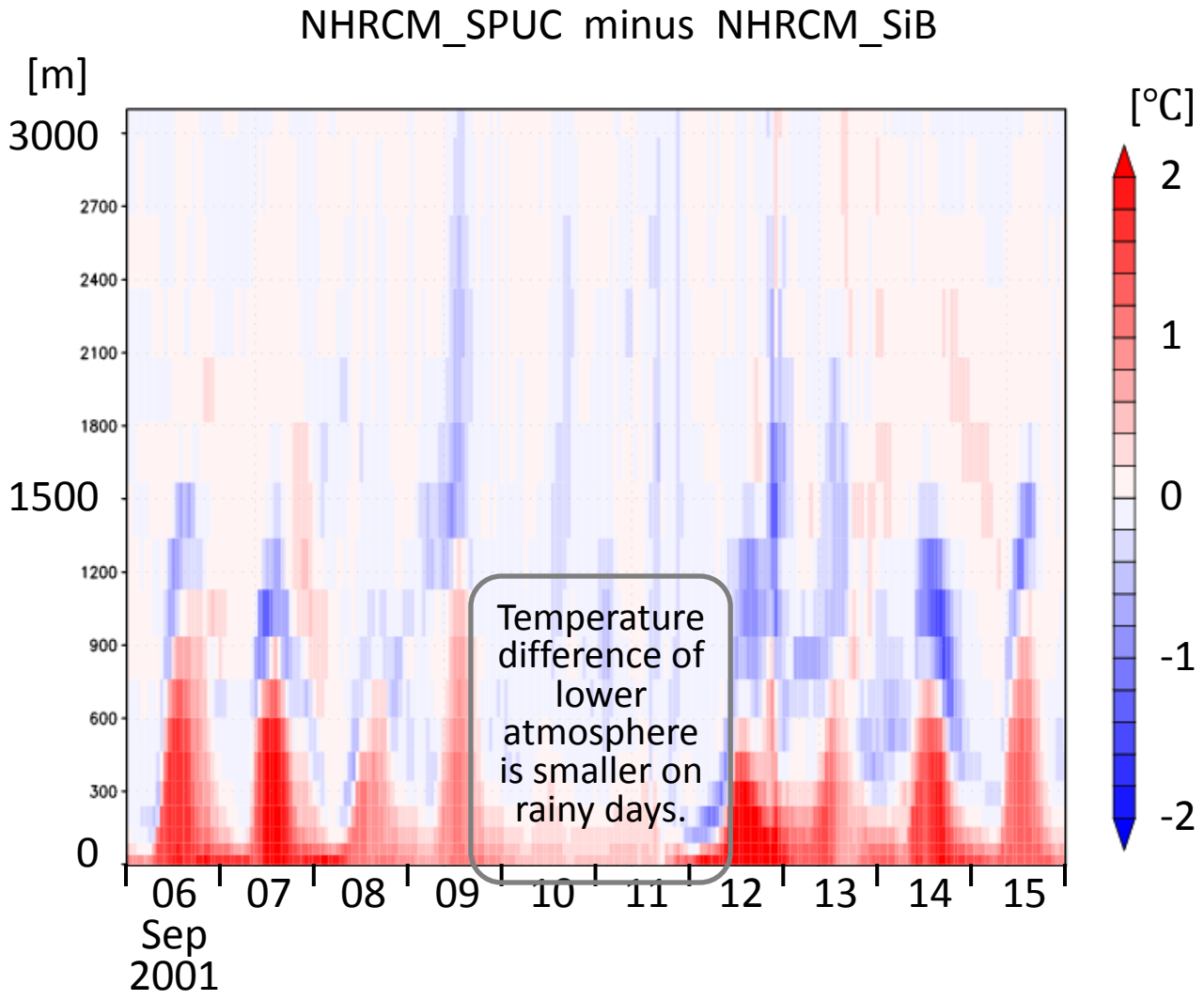
Corr. Coeff. 0.70 → 0.70

Result (Precipitation)

- The total amount of precipitation
  - Precipitation rates and its spatial correlations are almost the same between two experiments (NHRCM_SiB and NHRCM_SPUC)

- The influences of temperature change at the surface could not reach to the upper air?
- Are the temperature changes so small that they do not give any influences on precipitation?

Result (Difference of daily potential temperature profile over urban grids)



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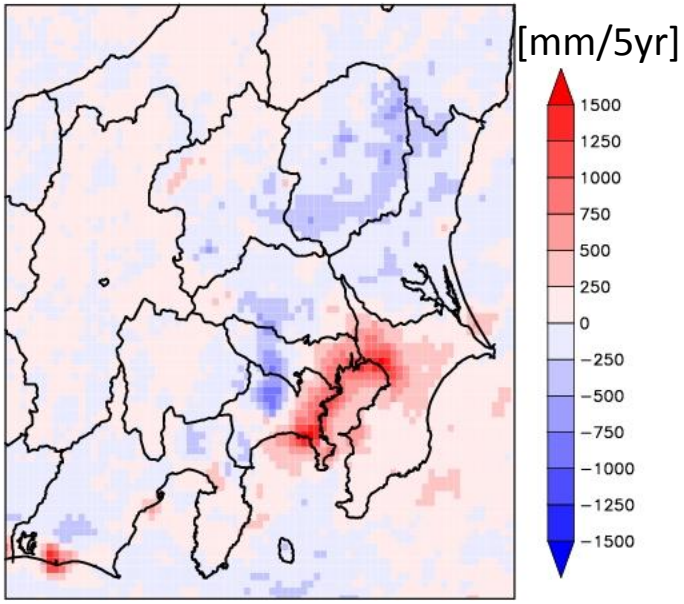
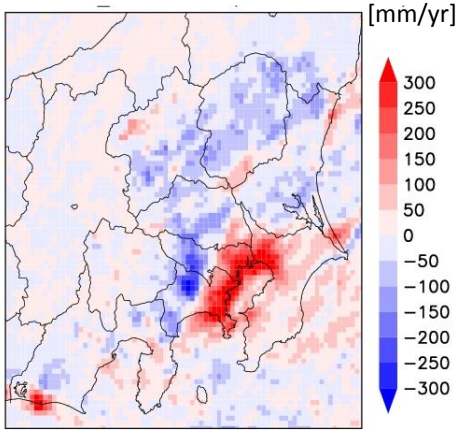
- The influences of the surface temperature change could not reach to the upper air?
- Are the temperature changes so small that they do not give any influences on precipitation?

Differences of total amount of precipitation between the experiments of NHRCM_SPUC and NHRCM_SiB

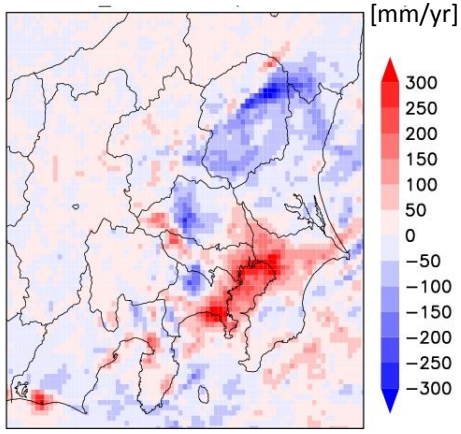
2001/09 – 2006/08



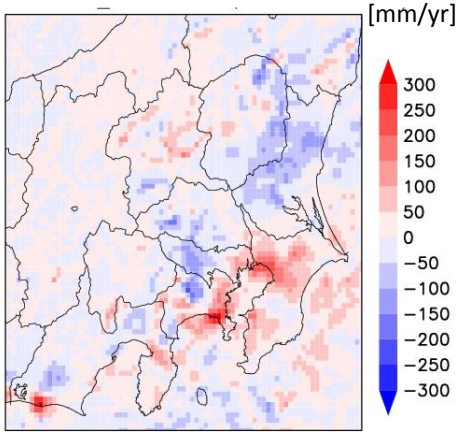
2001/09 – 2002/08



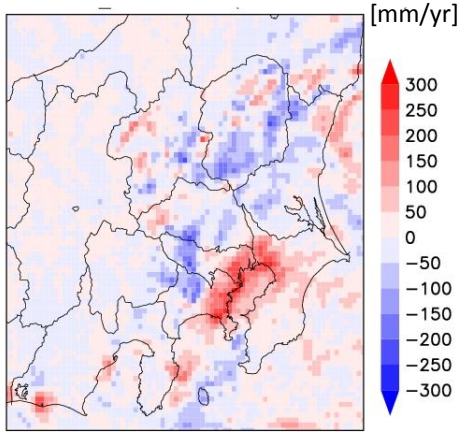
2002/09 – 2003/08



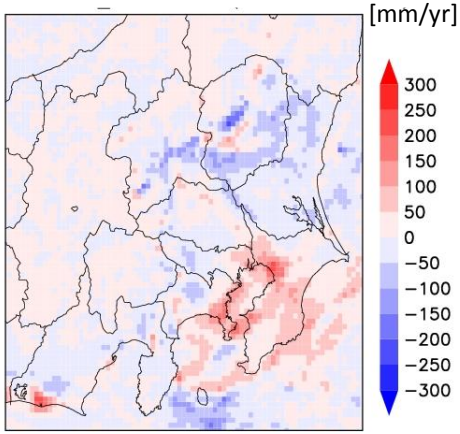
2003/09 – 2004/08



2004/09 – 2005/08



2005/09 – 2006/08



Result (Precipitation)

— differentials of two experiments —

- There *are* some influences of land surface change on precipitation.
  - The differentials are quite small compared with the interannual variation of precipitation (the influence on the climatology seems to be negligible).
- When the SPUC scheme is applyed ...
  - Precipitat
    coastal ur
  - Precipitat

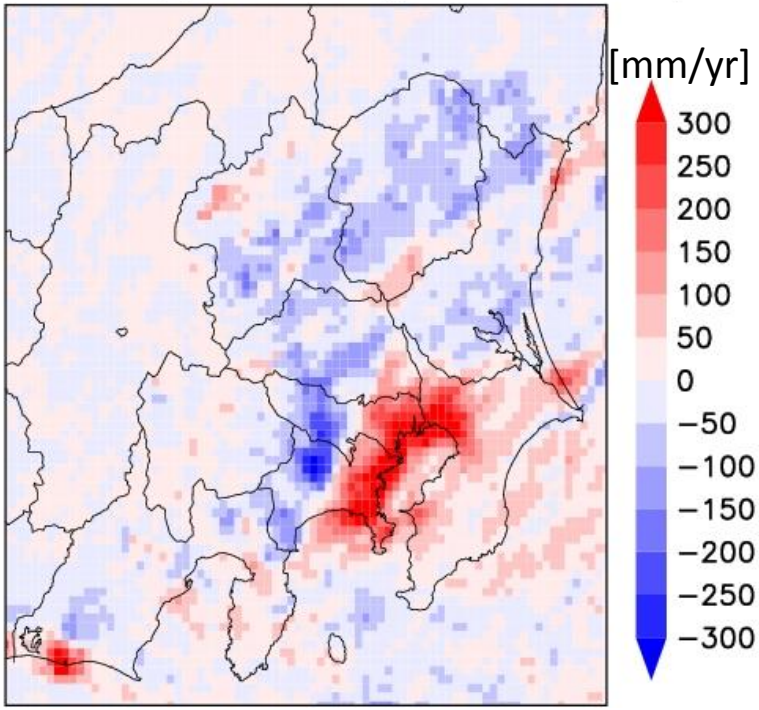
Qualitatively, this story could be acceptable.
Quantitatively, however, the precipitation amounts must depend on the parameters of cumulus convection parameterization scheme.

The lower atmosphere is warmed up
→ The atmosphere will be more un stable a bit
→ Convection will be triggered easier
→ Precipitation will be increased (decreased at downstream area)

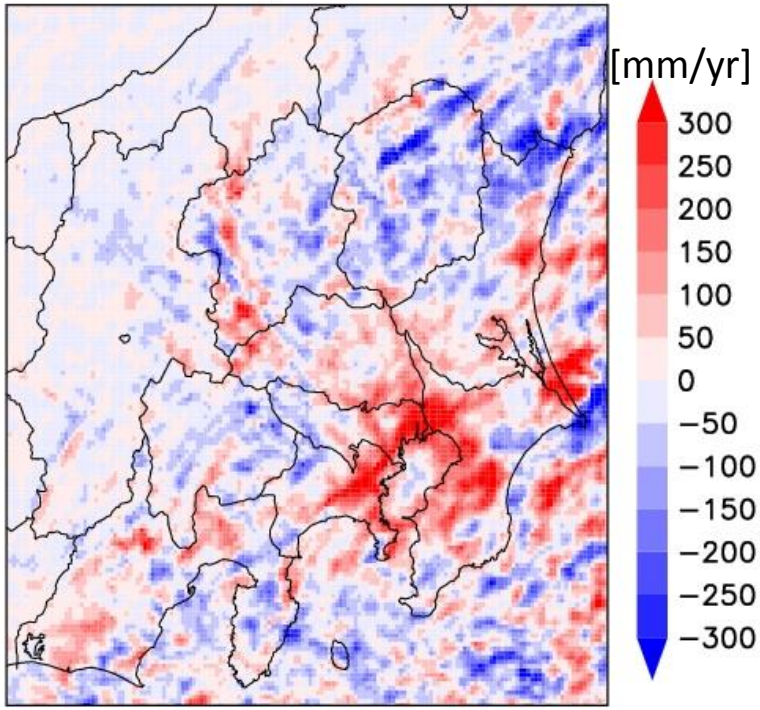
Additional experiment
--Dependence of the convection scheme--

Difference of annual precipitation (2001)
（NHRCM_SPUC – NHRCM_SiB）

NHRCM in 4km resolution
with the cumulus convection scheme



NHRCM in 2km resolution
without the cumulus convection scheme



Summary

- We checked the impact of NHRCM's land surface schemes for urban area on their climatic reproducibility.
  - Experiment with the MJ-SiB scheme only
  - Experiment with the SPUC scheme on urban grids

(Surface air temperature)

- When we applied the SPUC scheme on urban grids, the negative biases reproduced by the MJ-SiB was largely modified to be positive. The reproduction of spatial (horizontal) distribution of long term mean temperature was improved.
- The influence of the surface scheme change was also seen in vertical direction. The influence was limited below a several hundred meters during the night, otherwise, reached a few km in daytime.

Summary

(Precipitation)

- The influence of the scheme change in the urban grids on annual or 5-years total precipitation is quite limited.
  - On rainy days, the impacts of the land surface change are small.

- Although the influence is not contribute to the climatic statistics, a certain amount of increased precipitation over coastal urban area was found. However, the affected area and the differential amount of precipitation are likely to be dependent on the cumulus convection parameterization scheme used in the atmospheric model.

⇨ High-resolution (Δ < 2 km) simulations without any cumulus convection parameterization scheme are strongly needed to assess the impact of urban surfaces on precipitation.

Thank you for your attention!

This research is supported by SOUSEI program of MEXT, Japan.