Introducing Fractal Dimension into the Coupled WRF-Urban Model to Represent the Morphological Characteristics of Urban Canopy

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Introduction

- In WRF-Urban model, the percentage of impervious surface is used to characterize urban land-use condition, but it just a two dimension information, Which dose not consider the morphological characteristics of urban canopy.
- The height information is needed to introduce into model. It is difficult to get the building height.
- Fractal dimension can reflect the heterogeneity in vertical direction properly.

Outline

1. **Methodology**

2. **Validate the performance of the new approach(fractal dimension) in WRF-Urban Model**

3. **Conclusion**

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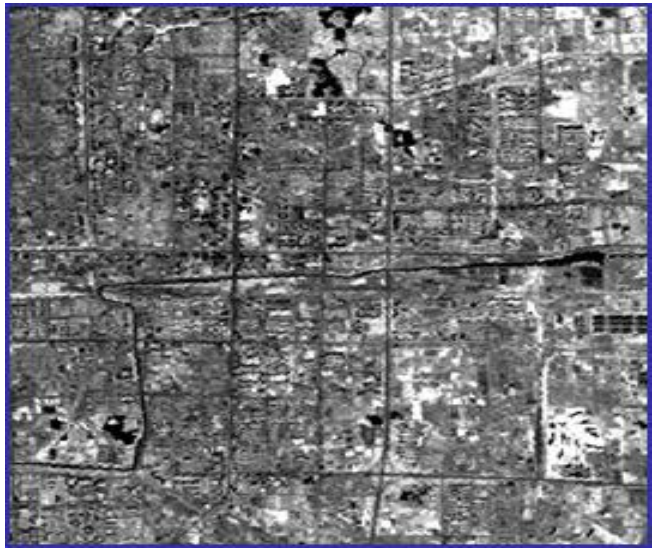
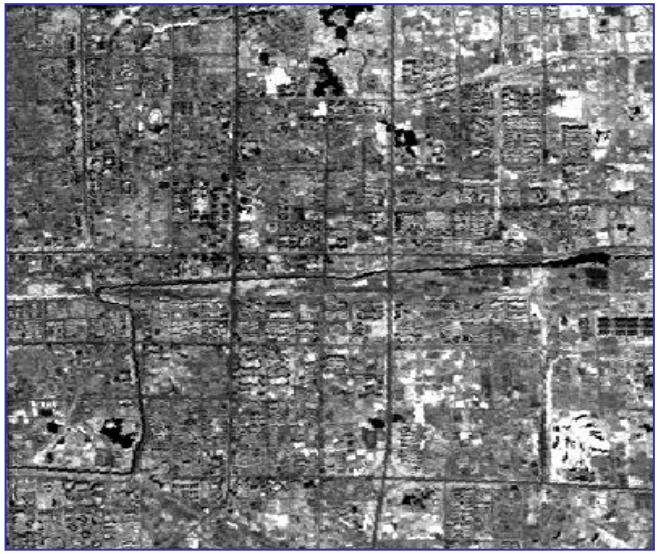
Methodology

Beijing underlying surface fractal dimension base on 2011 Landsat-TM remote sensing images.



Yaoyang Center Business District: 2.9847



Huilongguan residential area： 2.9054

Fractal dimension can reflect the complexity and degree of fragmentation of surface type, the higher fractal dimension means more complex type and higher fragmentation. Based on the above picture we could figure out that the fractal dimension order in Beijing is Commercial> Residential. Clearly, the fractal dimension could be a reflection of morphological information.

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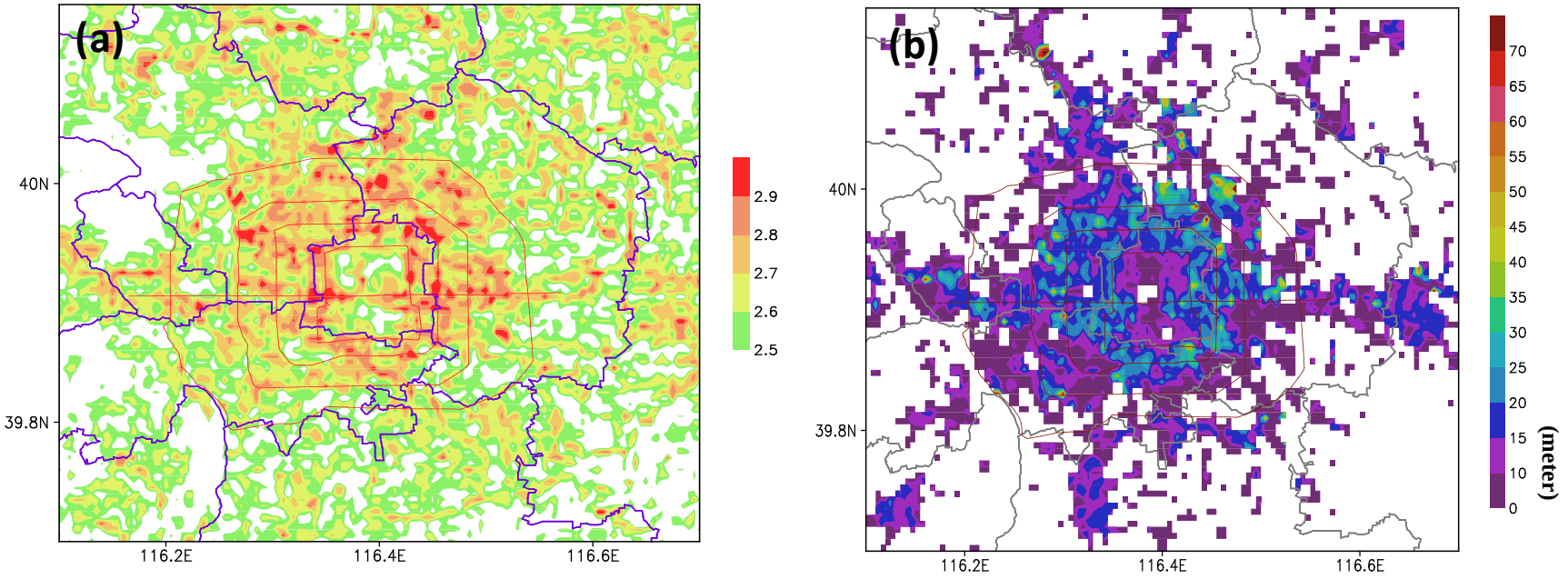
Figure a is the fractal dimension and figure b is the building height in Beijing.



The distribution of fractal dimension and height building are very similar. So fractal dimension can reflect the heterogeneity of urban land use condition in vertical direction. We derive the urban land-use categories and the corresponding average building height in the model.

Fractal dimension	2.35~2.62	2.56~2.75	2.75~3
Urban land-use categories	Low density	Medium density	High density
Mean height of building	8m	12m	16m

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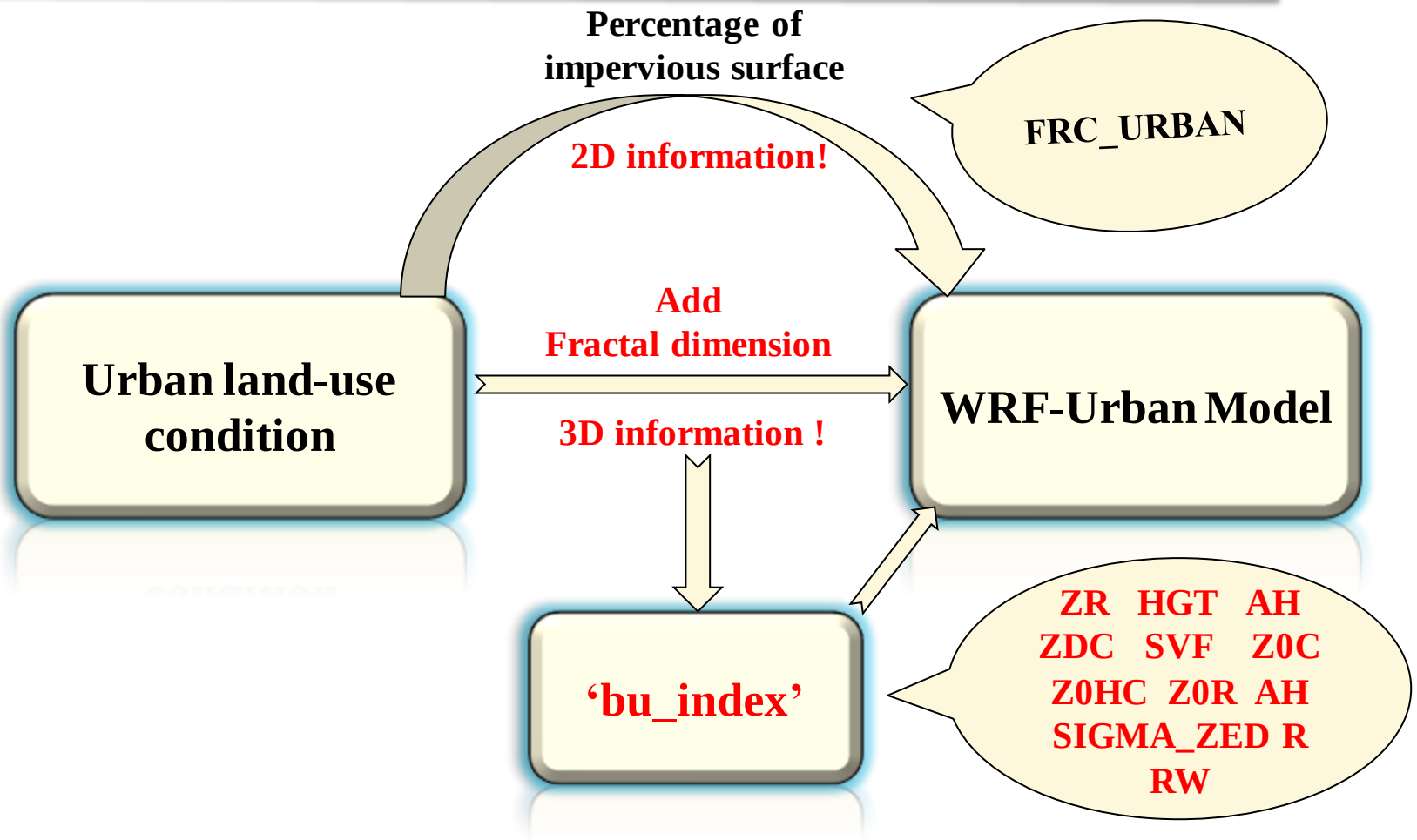
How to introduce fractal dimension into Model



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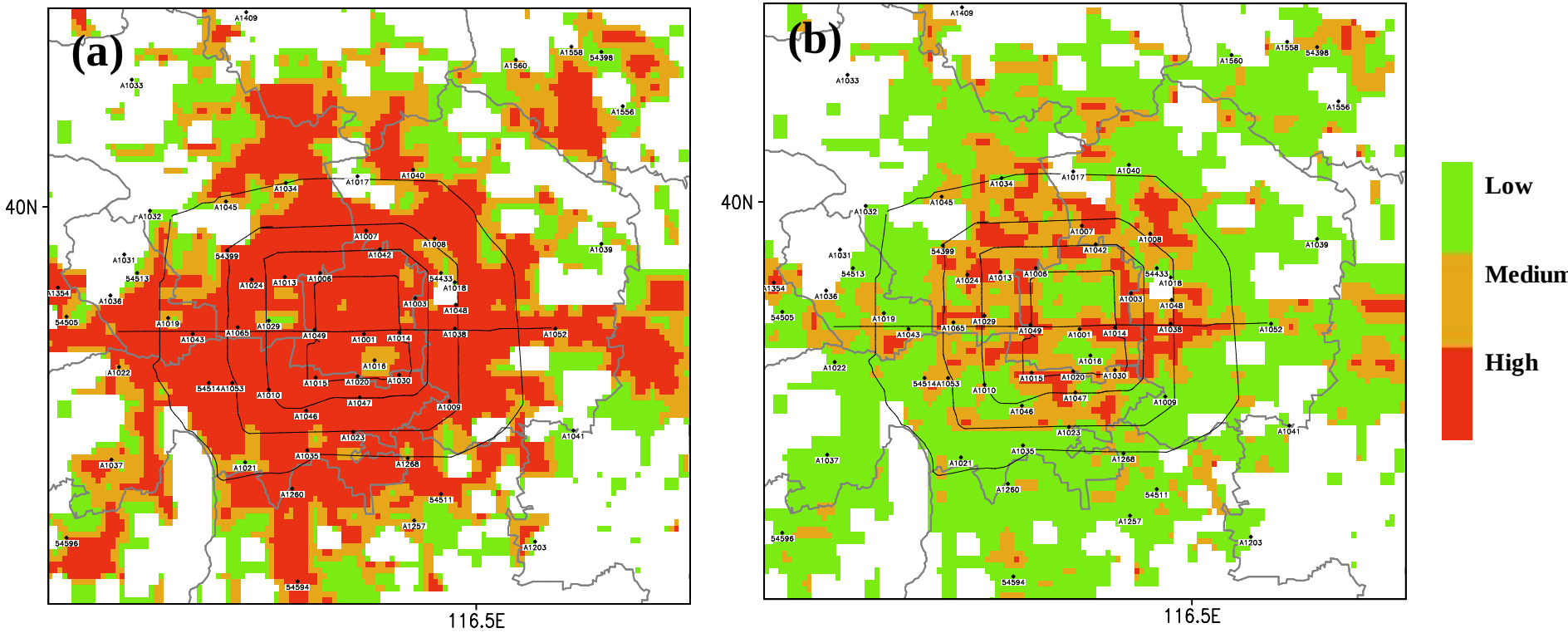
Beijing urban land-use categories in WRF-Urban model



Their difference is figure a is only corresponding the percentage of impervious surface, but figure b corresponding both percentage of impervious surface and the fraction dimension. obviously, figure b is more effective to describe the heterogeneity of city surface.

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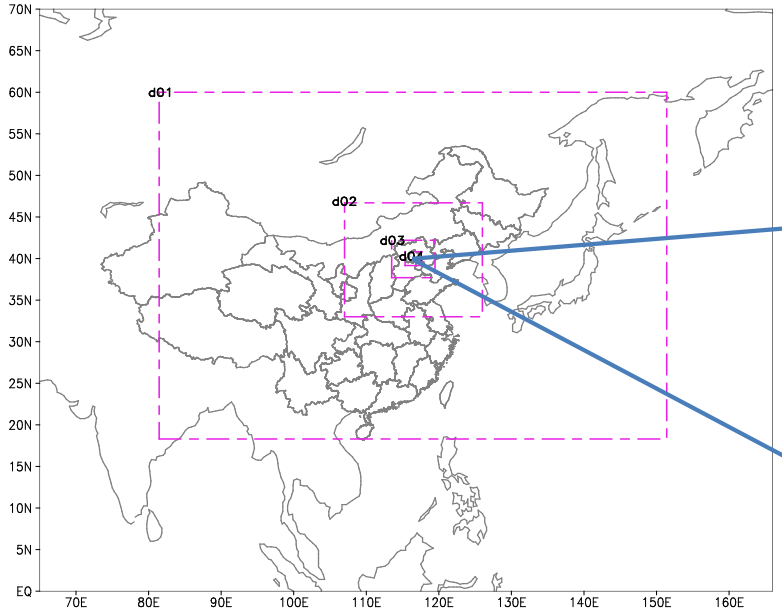
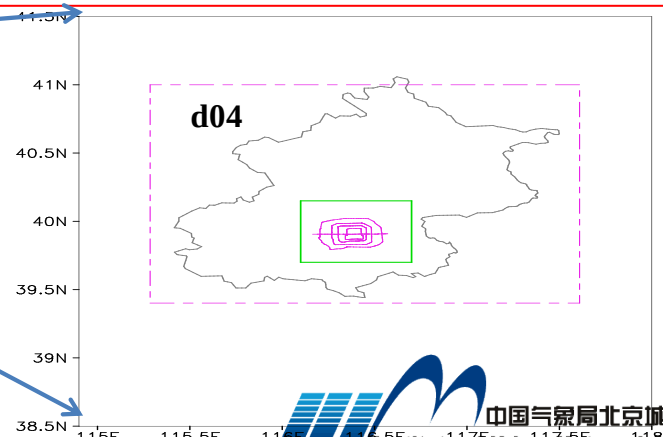
Numerical domain and setup of the simulation

- **Case1** A clear day at 6 August 2010. From 06:00UTC to 07:00UTC
  Case2 A rainfall day at 1 July 2013. From 01:00UTC to 02:00UTC

- Each case conducts two tests which are referred as ‘CTRL’ and ‘NEW’.
  The test NEW introduce fractal dimension based on test ctrl.
  A third test with no urban in Beijing is conducted in Case1 which is referred as ‘nobjcity’.

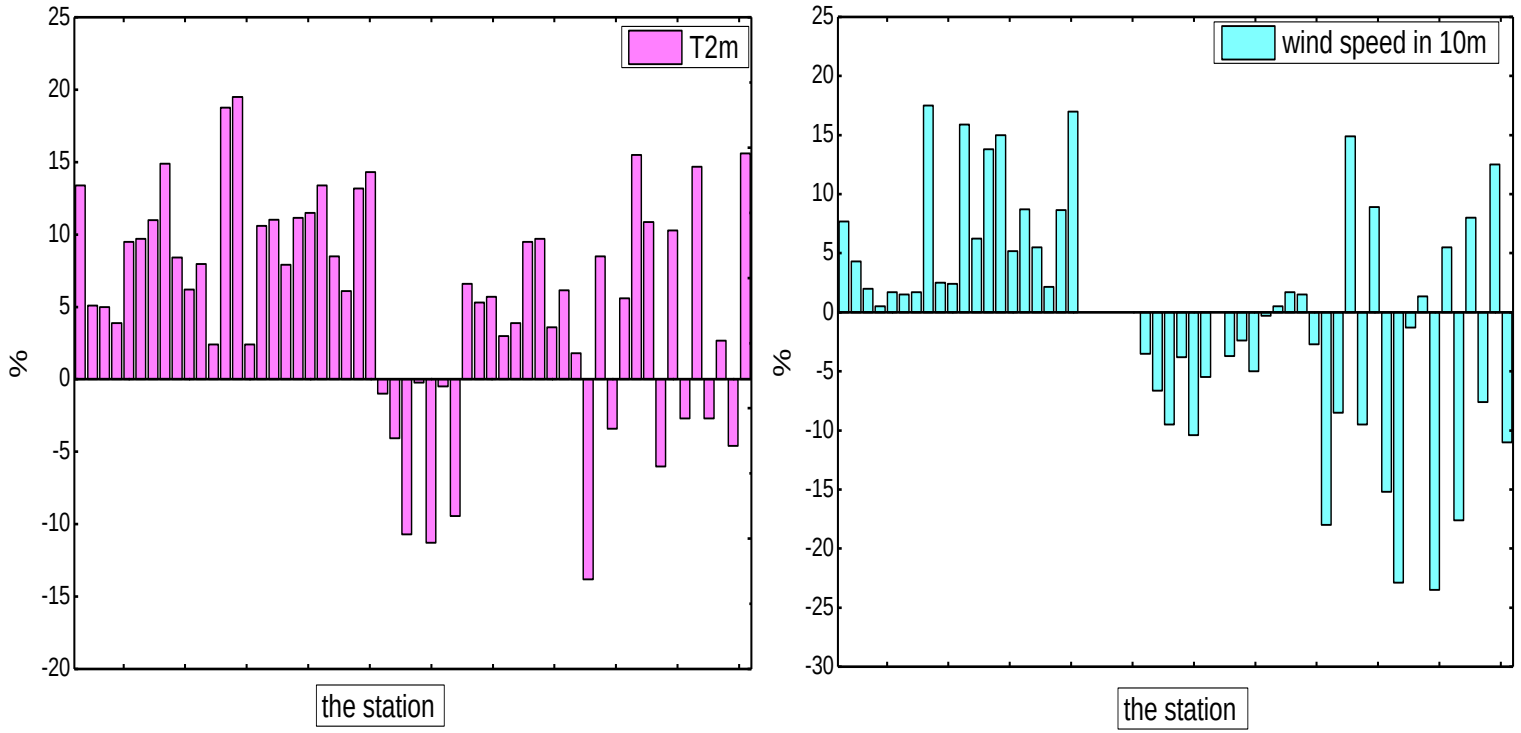
Four nested domains with horizontal spacing of 27km,9km,3km,and 1km. The region in green line is the focus area of this study. The red lines are the ring roads in Beijing.





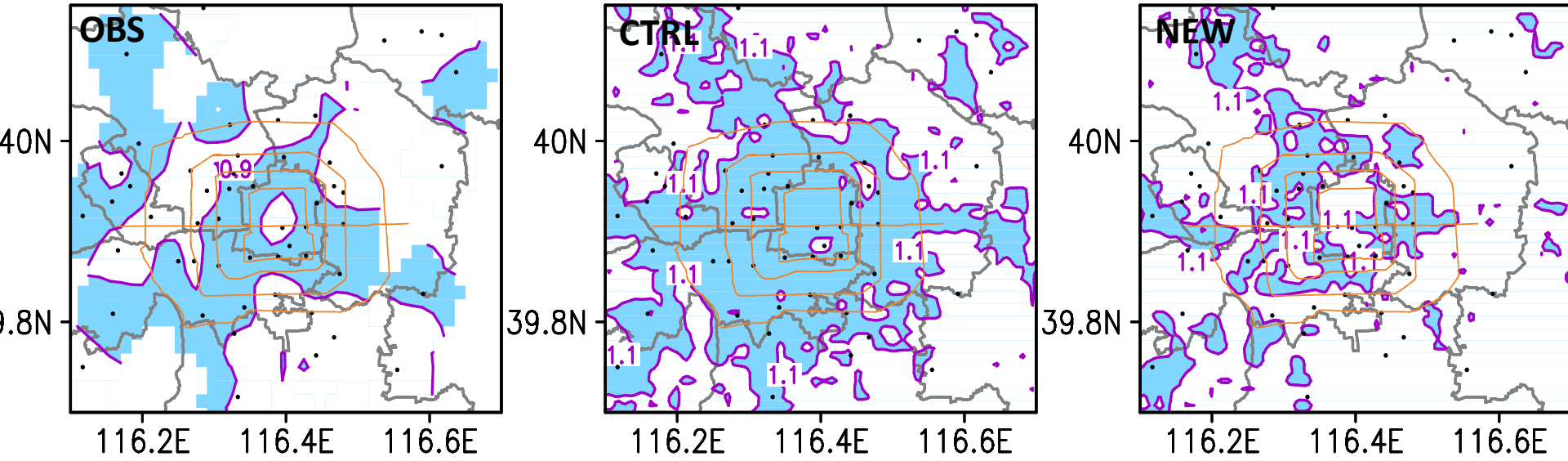
Analysis of the results(Case1)

Evaluation of T2m and wind speed in 10m against 77Automatic Weather Stations



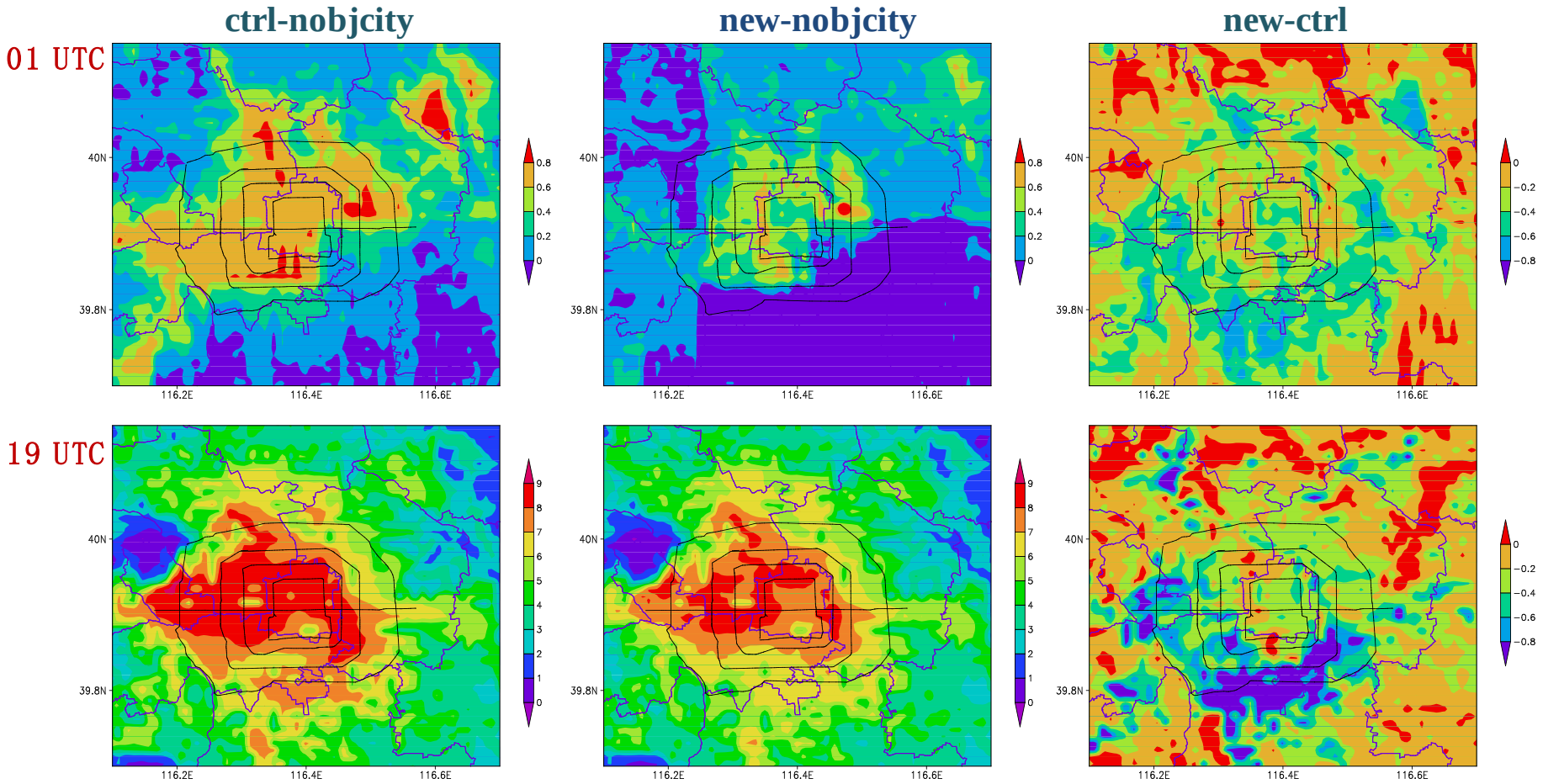
Positive value indicate that the test NEW perform better than test CTRL. Apparently, The test NEW shows better performance than the test CTRL in capturing the T2m.

The distribution of wind speed in 10m



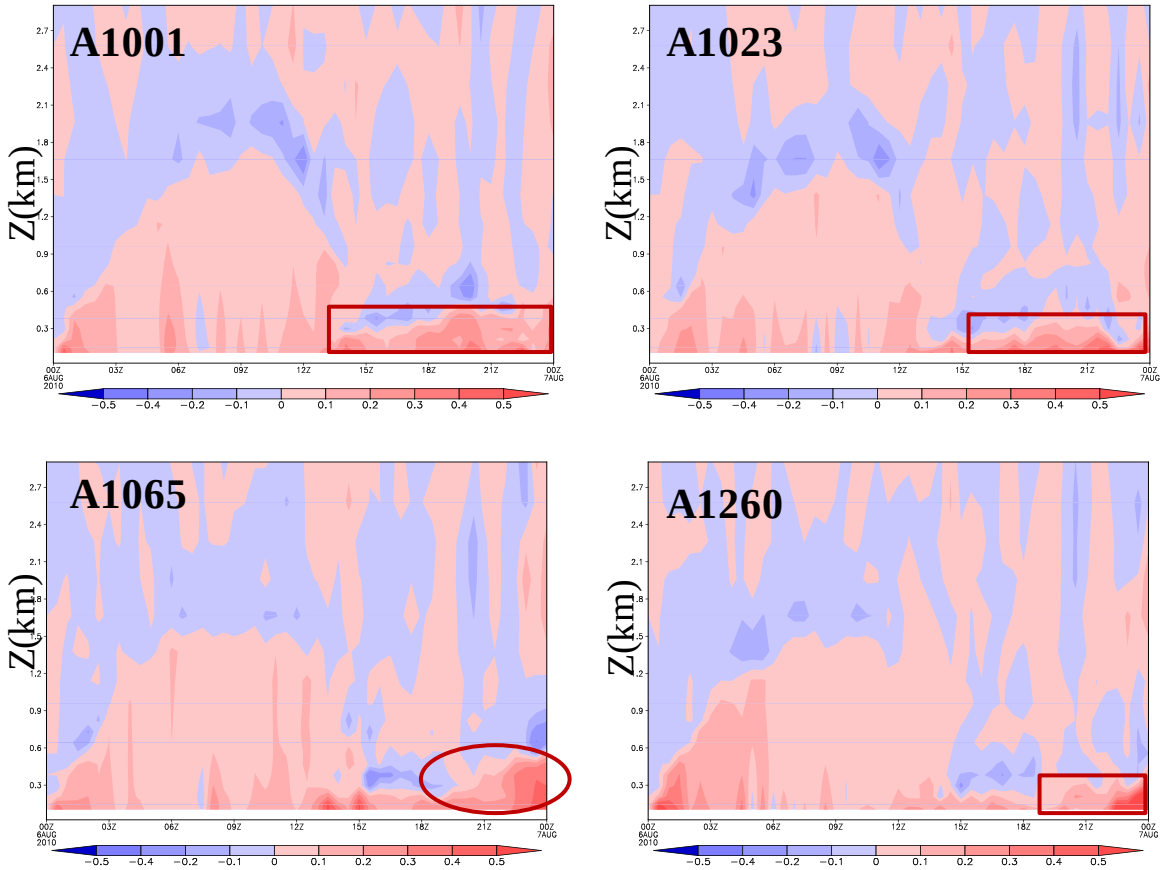
Shaded areas represent wind speed in 10m which is less than a certain threshold . Test New is more closed to the observation, the wind simulation is smaller between the second and fourth ring roads in Beijing which correspond with the high rise building region.

The difference of T2m between three tests are shown.

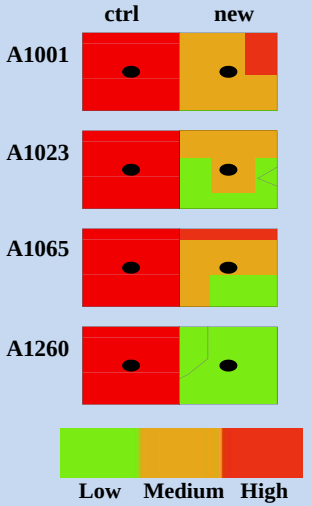


In 01 UTC, the difference of T2m between test CTRL and test nobjcity show the characteristics of the percentage of impervious surface. After introducing fractal dimension it not only show the characteristics of impervious surface ,but also show the heterogeneity of urban land use in the vertical direction. But with the increasing of time, this feature tend to be indistinct. Maybe it is covered by thermal advection or other meteorology fields.

The difference of temperature profile(CTRL minus NEW) in four Automatic Weather Stations.



The surrounding urban land-use categories of the four stations.



It shows that when change the land use categories from high density to low(or medium) density, the temperature tend to be decreased for 0.5℃ and its impact height can reach 300 meters. Furthermore, the most significant influence happen during night.

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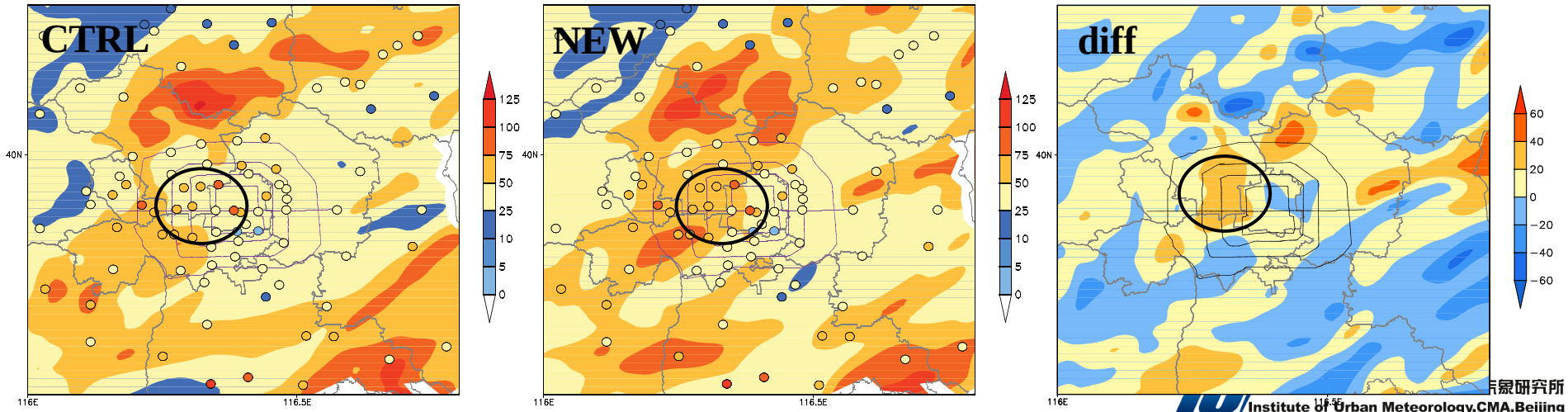
Analysis of the results(Case2)

Threat Score (Bj_urban)	Ctrl	New
(10,25]	0	0.5
(25,50]	0.60526	0.5263
(50,100]	0.25	0.55

The new test have a better performance in strong precipitation.

Test NEW produce more precipitation in the west of Beijing urban than test CTRL, and correspond with the observation.

Total rainfall from 1 July to 2 July(00UTC to 00 UTC) produced by WRF and measured by the AWs



Conclusion

- After introducing fractal dimension , model shows better performance in capturing the T2m and the distribution of the speed in 10m.
- When the land use categories change from high density to low density, the temperature get colder. the most significant influence happen during night.
- After introduce the fractal dimension, the model performance better in strong rainfall.
- Introducing fractal dimension into the coupled WRF-Urban Model can improve the description of the urban covers, and could provide more accurate forecasts for urban regions.

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Thank you !

Appreciate your advice !