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Simulation studies for Lake Taihu effect on local meteorological environment

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Outline

- Background
- Experimental design
- Result and discussion
- Next work

Background

- Taihu Lake is the largest shallow lake in eastern China, with the area of 2338km^2 and the average water depth of 1.9m. The local thermal circulation triggered by the thermal environment differences between the surrounding land affects the atmospheric environment and the diffusion and transport of pollutants
- The coupling of the parametric schemes of the lake surface process in the climate model is very important for the dynamic prediction of lake interaction. It is necessary to study the applicability of lake process and lake interaction to local weather and climate, and to carry out lake model suitability in the lakes of China.

Research content

- This study couple the CLM4-LISSS（Community Land Model version 4- Lake, Ice, Snow, and Sediment Simulator）（Subin,et al,2012）shallow lake land-surface process parameterization scheme to the Noah land-surface process model in WRF and evaluate the simulation performance of CLM4-LISSS , CLM4.5（Oleson,2010； Subin,et al,2012 ）and Noah（MB et al.，2003）land-surface process scheme on the near-surface meteorological conditions in the region of Lake.
- The meteorological environment of Taihu Lake and surrounding cities in January, April, August and November was simulated to discuss the influence of Taihu Lake on the local climate. The study could provide theoretical basis for the improvement of urban climate and atmospheric environment.。

Experimental design

➢1、WRF model and coupled lake land surface process parameterization scheme.

- CLM4-LISSS and coupled with WRF / Noah

CLM4-LISSS is an improved version of the CLM4 land surface process model, making it ideal for a wide range of weather and climate studies. Deng Bin (2013) improved the CLM4-LISSS lake model to make it better in the simulation study of shallow lake in Taihu Lake. In this paper, the land surface process model (CLM4-LISSS) suitable for shallow lakes is coupled into the WRF mode.

- The default lake land surface calculation process in Noah model

At present, the Noah land surface process model for lake-air exchange is calculated by sea surface temperature instead of large area of lake surface temperature.

- Lake land surface process model CLM4.5（Community Land Model 4.5）（WRFV3.7.1）

The Community Land Model version 4.5 (Oleson et al., 2013) lake model, denoting the Lake, Ice, Snow, and Sediment Simulator (LISSS) had been coupled into the Weather Research and Forecasting (WRF) Model in version 3.7.1. It contains a 1D thermal diffusion lake scheme which is modified by Gu et al. (2015). Actual lake depth can be employed in the lake scheme. The physical process is based on Hostetler and Bartlein (1990), Bonan (1995), and Subin (2012).

Experimental design

➢ 2、Mode example setting

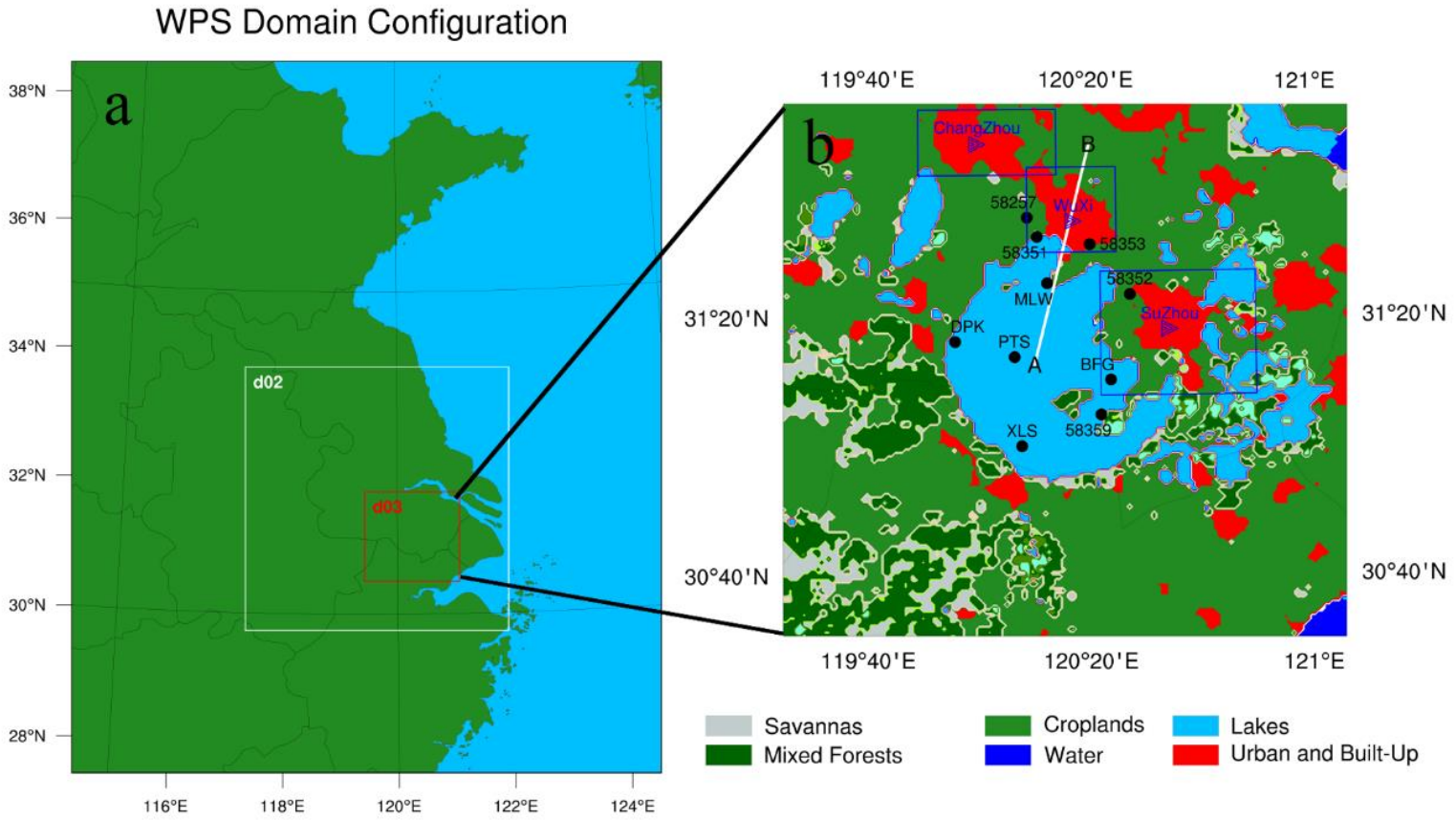


Fig 1. The WRF model domain a. the three nested meshes with horizontal resolution of 9,3,1km; b. the land-use categories over the innermost domain(The line AB denote the location of vertical cross-section in Fig 9 – 12 and the black dots denote the observation stations)

Table 1. The design of numerical simulation

Experiments	Noah	CLM4.5	CLM4-LISSS	Nolake
WRF version	WRF3.3.1	WRF3.7.1	WRF3.3.1	WRF3.3.1
Time	2015-08-01～2015-09-01			
Centerpoint lon/lat	33.05°N，119.44°E			
Nests	113×136；151×151；163×154			
Grid length	9km；3km；1km			
Time step	18s			
Eta levels	53			
Geog	Modis	Modis_lakes	Modis_lakes	Modis_lakes (without lake)
Initial boundary condition	The NCEP FNL (Final) Operational Global Analysis data			
Land-surface option	Noah	CLM4.5	CLM4-LISSS	CLM4-LISSS
Urban canopy model	Building Environment Parameterization (BEP) scheme（Martilli，2009）			
Microphysics option	WRF Single-Moment 3-class (WSM 3-class) simple ice（Hong et al.，2004）			
Longwave radiation option	rapid radiative transfer model（rrtm）（Mlawer et al.，1997）			
Shortwave radiation option	Dudhia（Dudhia，1989）			
Boundary-layer option	Bougeault and Lacarrere（Bougeault，1989）			
Surface-layer option	Monin-Obukhov（Paulson，1979）			
Cumulus option	Kain-Fritsch（Kain and Fritsch，1990,1993）			

Result and discussion

- 1、Evaluating the Simulation Performance of the land-surface process parameterization scheme to the Meteorological Conditions of the Nearshore in the Taihu Lake Region

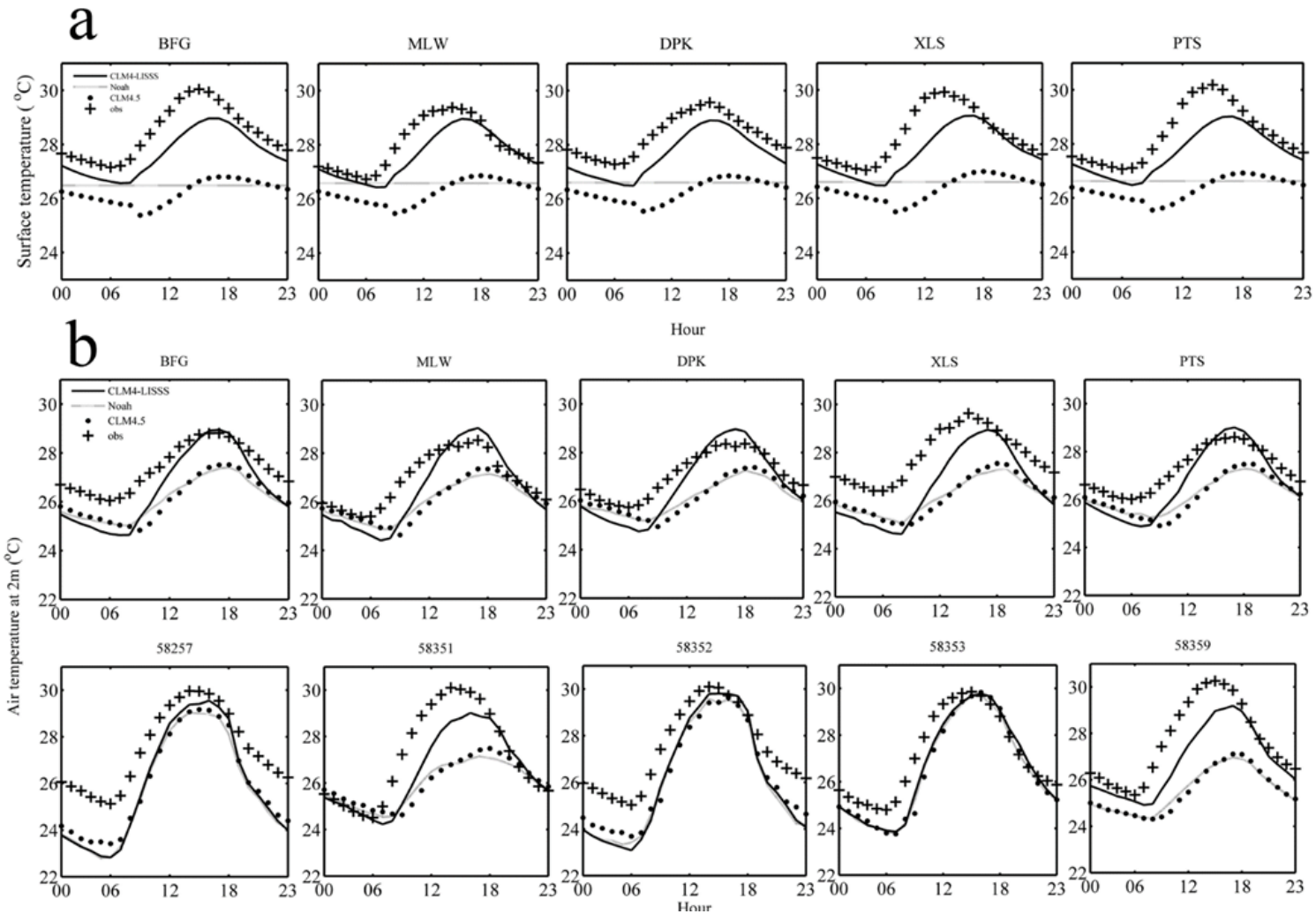


Fig 2. Comparison of simulated mean interdiurnal variation (units: hour) of 2m temperature (units:℃) and surface temperature (units:℃) with the mean interdiurnal variation of observed results at Lake Taihu area(Fig 1b)

Result and discussion

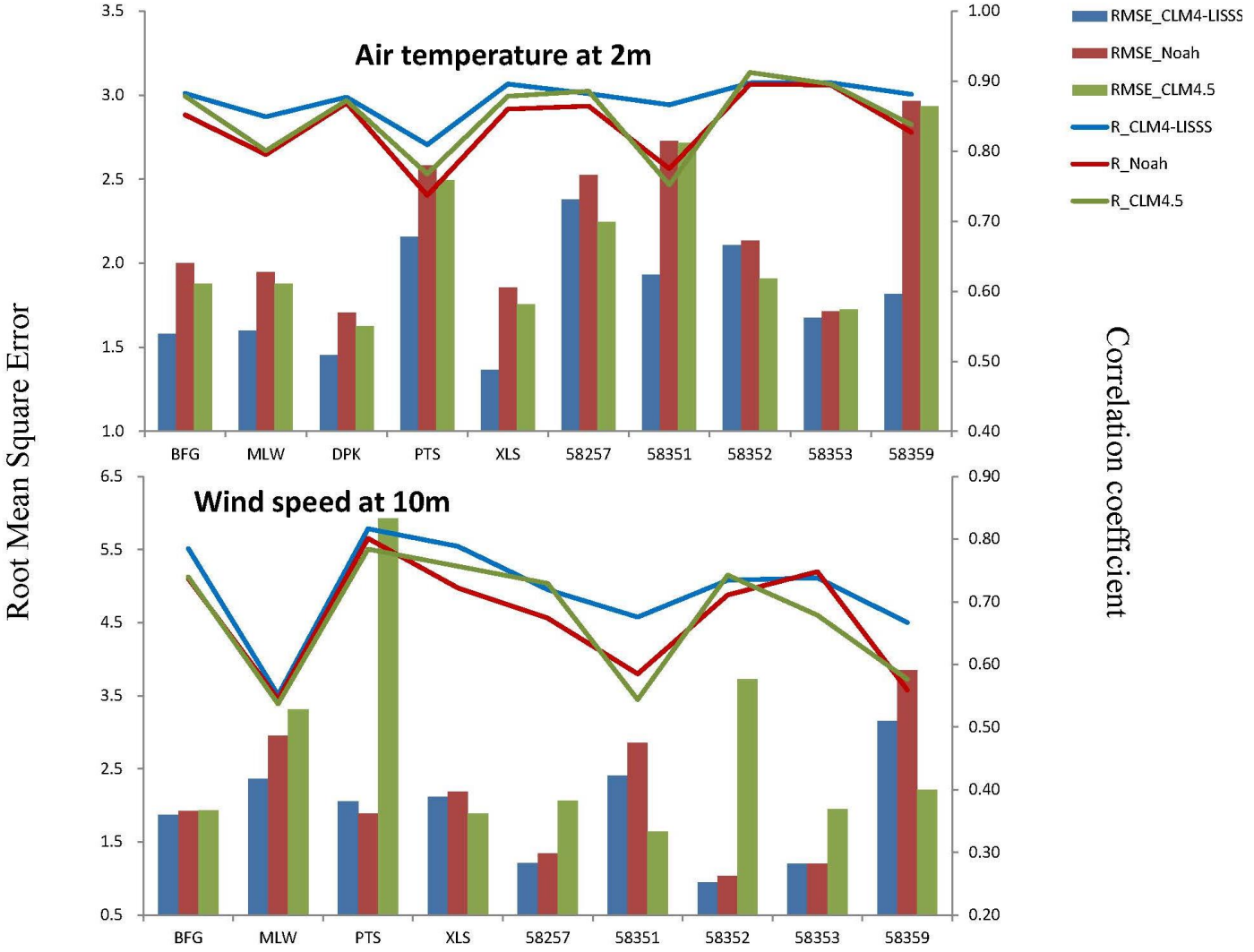


Fig 3. Root mean square(Histogram) and correlation coefficient(solid lines) of the simulated 2m temperature(a) (units:℃) and 10m wind speed (b)with three land surface process parameterization scheme

1、The Impact of Taihu Lake on Local Meteorological Environment

- Influence of Taihu Lake on the Temperature in the near area

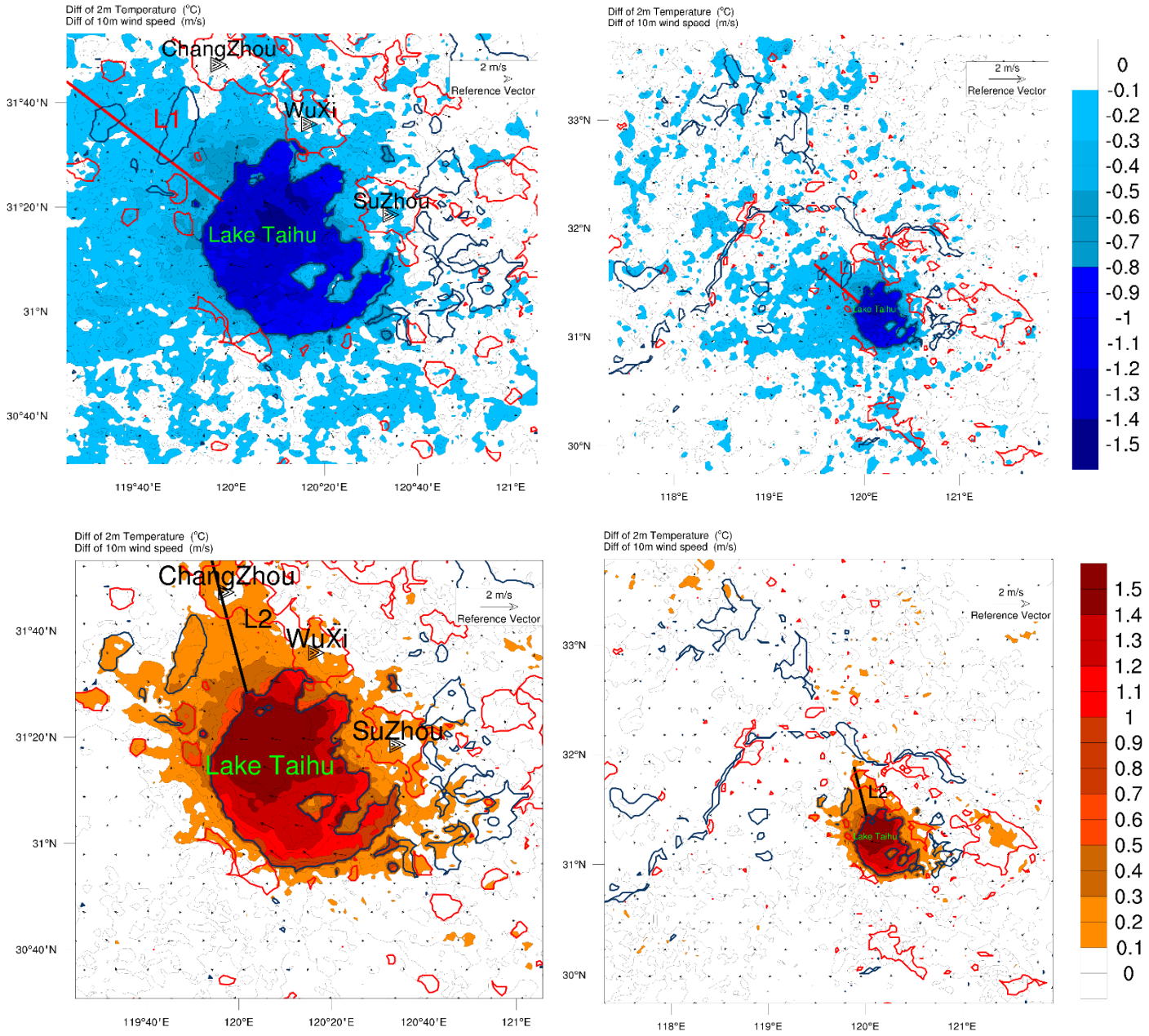


Fig 4. Differences in averaged 2m temperature(shadows ;units: ℃) and 10m wind field (arrows; m/s) between Lake and Nolake experiments at 15:00 and 06:00 (BT) in August, 2015. (a: the innermost domain; b: the second domain; the red lines :urban areas; the mazarine lines: lake areas ;)

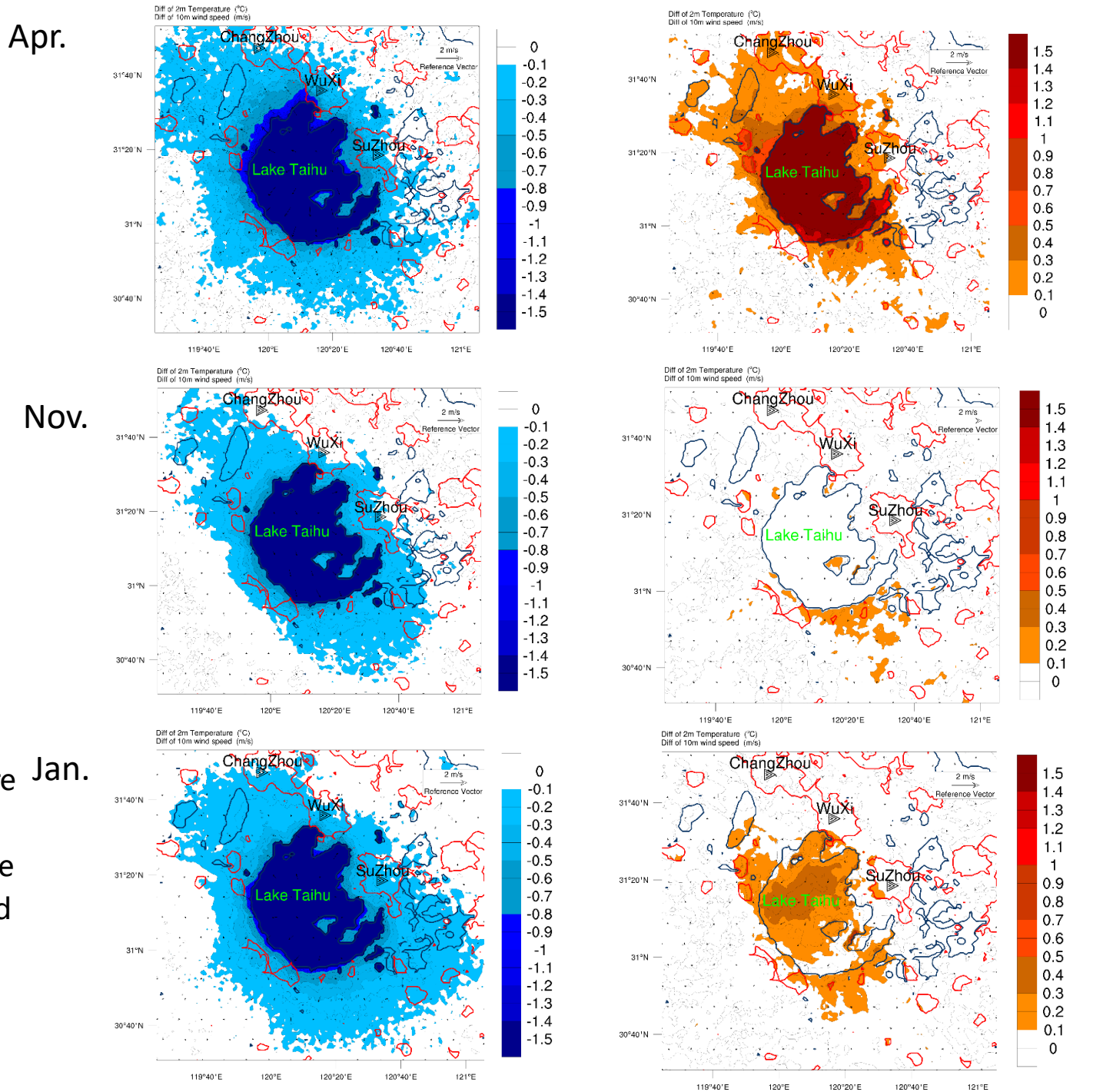


Fig 5. Differences in averaged 2m temperature and 10m wind field between Lake and Nolake experiments at 15:00 and 06:00 (BT) in April, November and January, 2015.

- Influence of Taihu Lake on Temperature in Peripheral Boundary Layer

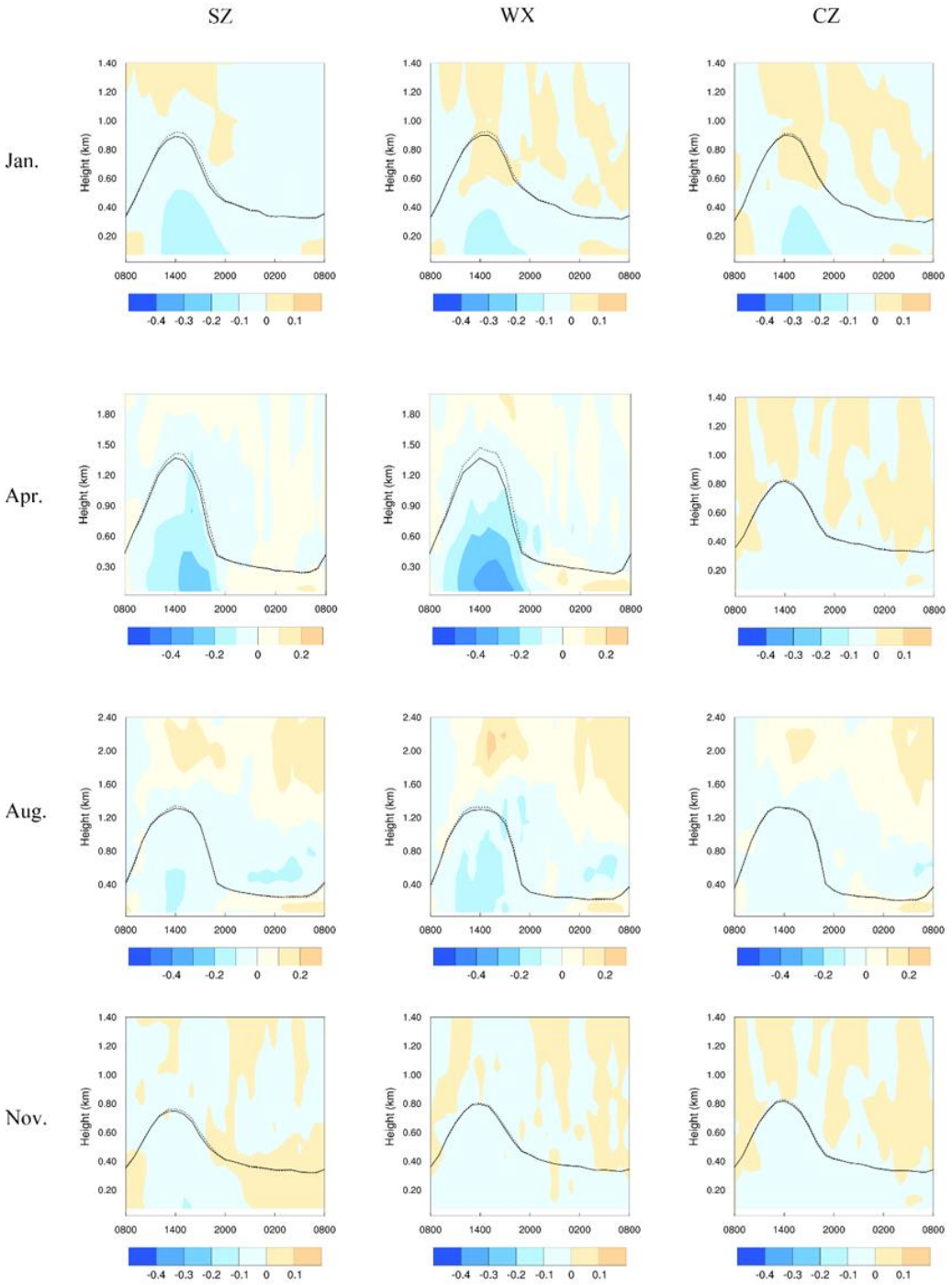


Fig 6. Variations of area-averaged PBL height (solid line: Lake, dotted lines: Nolake; units: km) from Lake and Nolake experiments, and profiles of area-averaged temperature difference (shadows ; units: ℃) between Lake and Nolake experiments over Suzhou, Wuxi, Changzhou at Janurary, April, August and Noveber ,2015

- The impact of Taihu Lake on the temperature of the surrounding city boundary layer (a continuous high temperature weather process August 1 - 6)

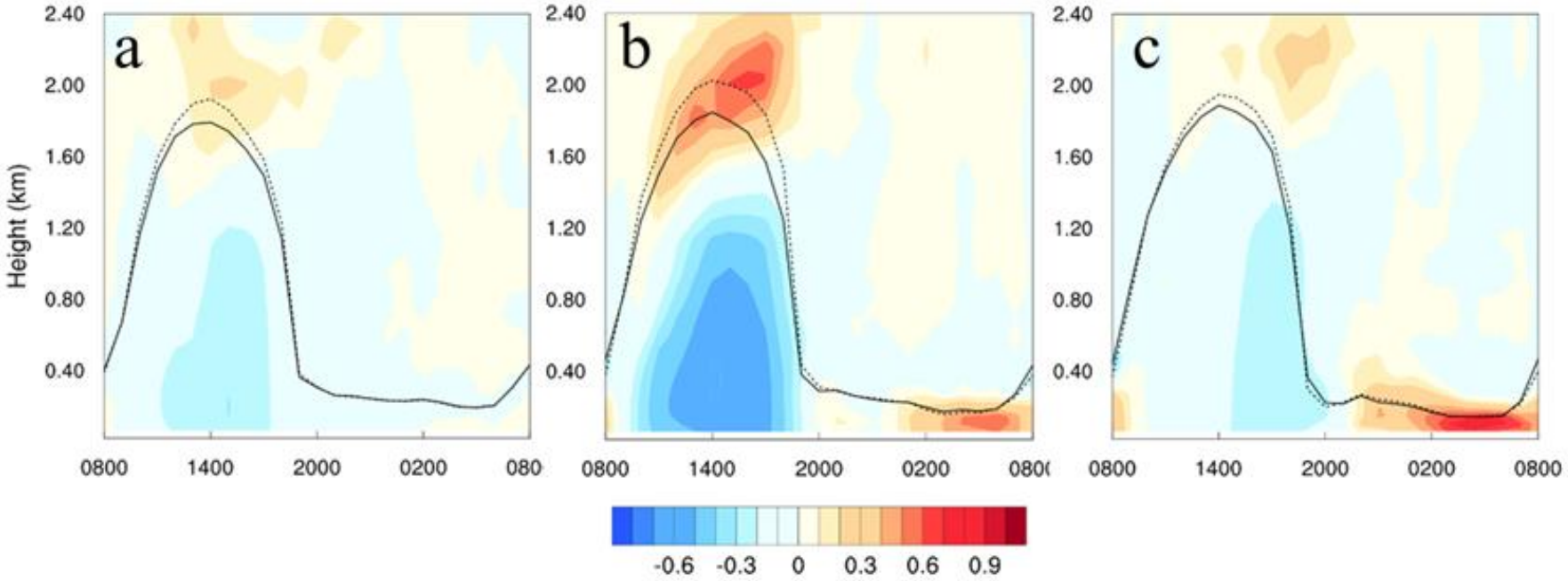


Fig 7. Variations of area-averaged PBL height (solid line: Lake, dotted lines: Nolake; units: km) from Lake and Nolake experiments, and profiles of area-averaged temperature difference (shadows ; units: ℃) between Lake and Nolake experiments over (a)Suzhou,(b)Wuxi.(c)Changzhou at August 1-6 ,2015

Influence of Taihu Lake on the specific humidity in the near area

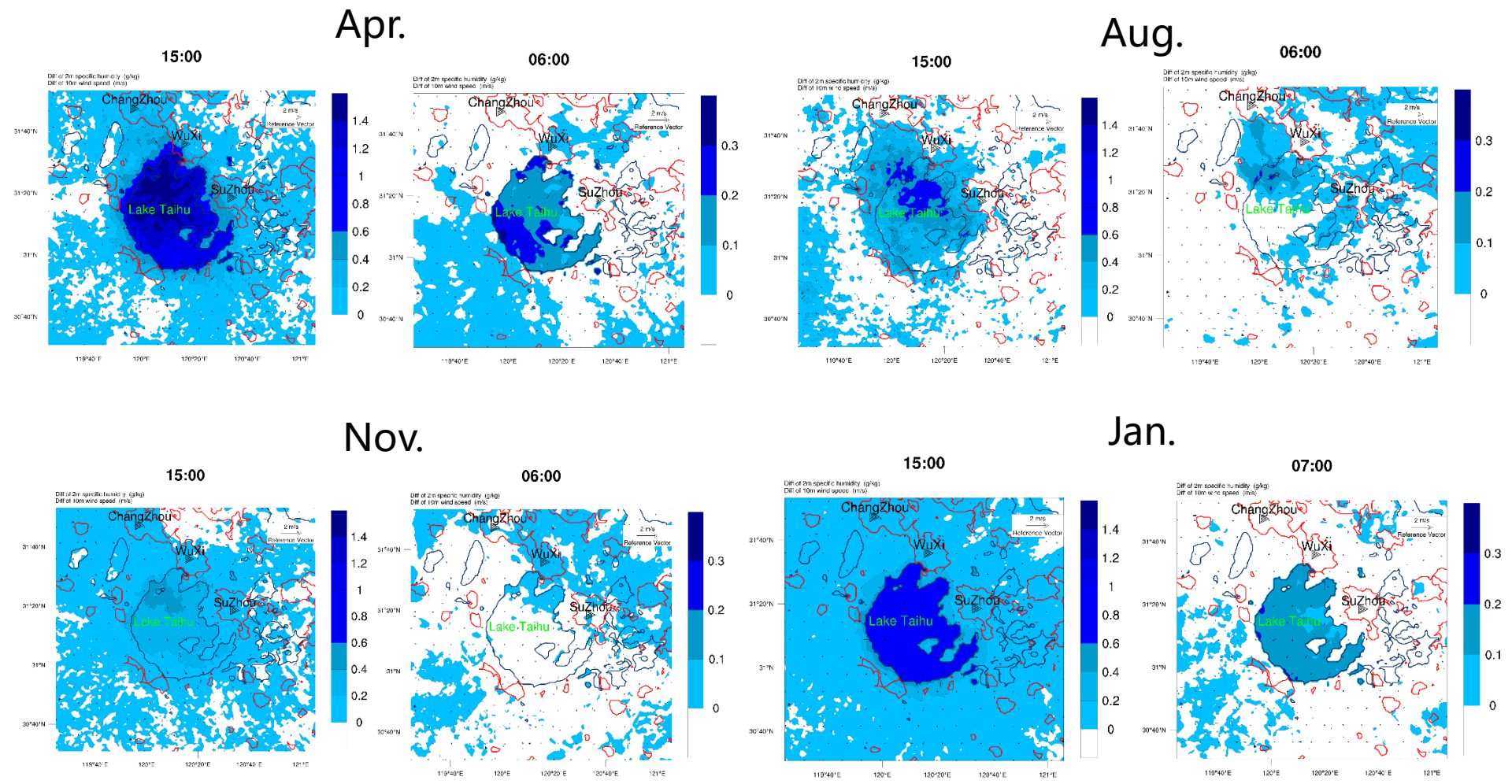


Fig 8. Differences in averaged 2m specific humidity (shadows ;units: k/kg) and 10m wind field (arrows; m/s) between Lake and Nolake experiments at 15:00 and 06:00(BT)(07:00 in January) in 2015

The Influence of Taihu Lake on Urban Heat Island

Aug.

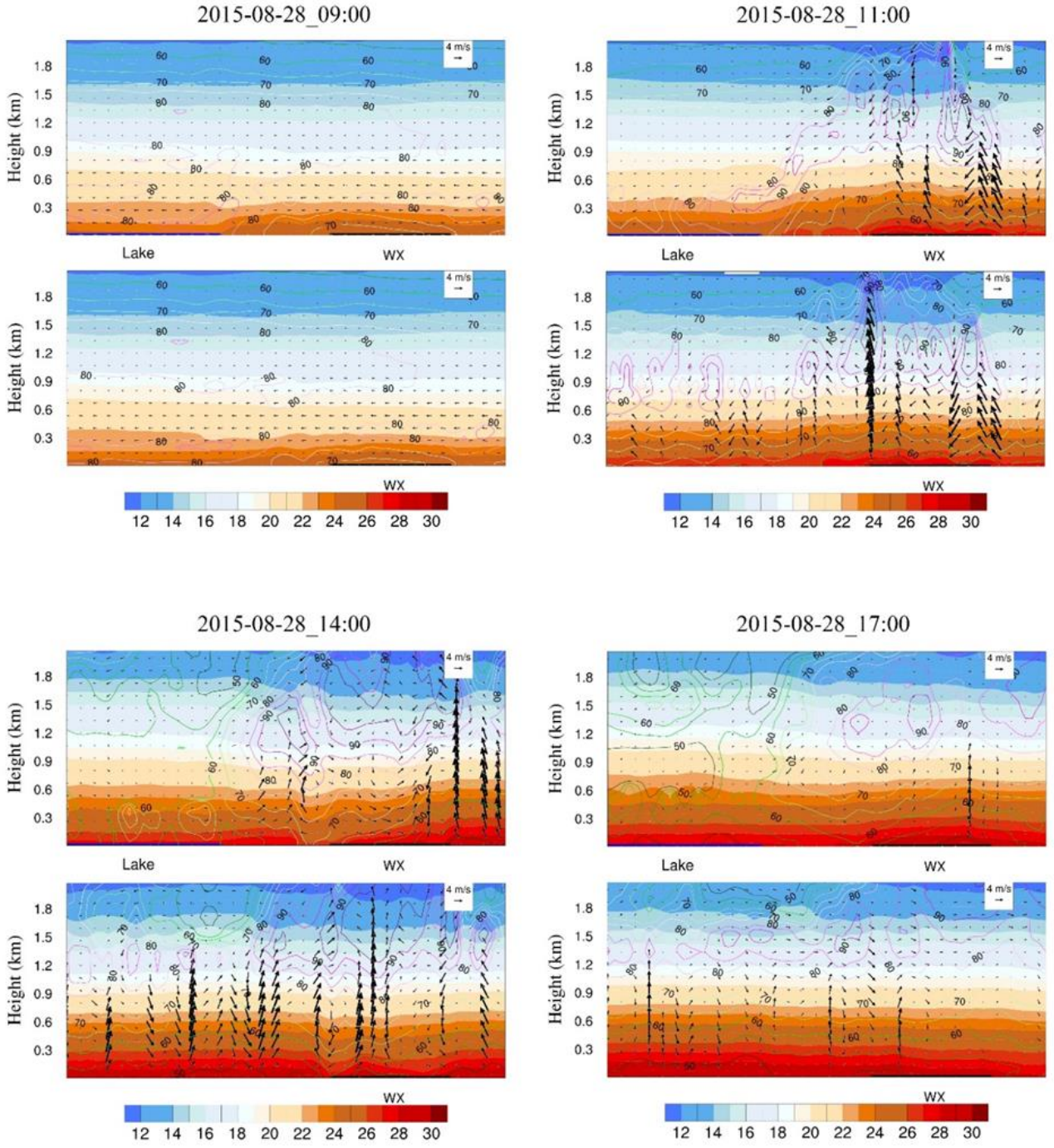


Fig 9. Vertical cross-sections of temperature(color shadows; units: ℃) 、 in-plane flow vectors(arrows;units:m·s-1)and relative humidity (color lines; units: %) in Lake and Nolake experiments alone line AC(Lake Taihu-Wuxi) at 09:00、11:00、14:00、17:00 BT in August 28,2015

- The Influence of Taihu Lake on Urban Heat Island

Apr.

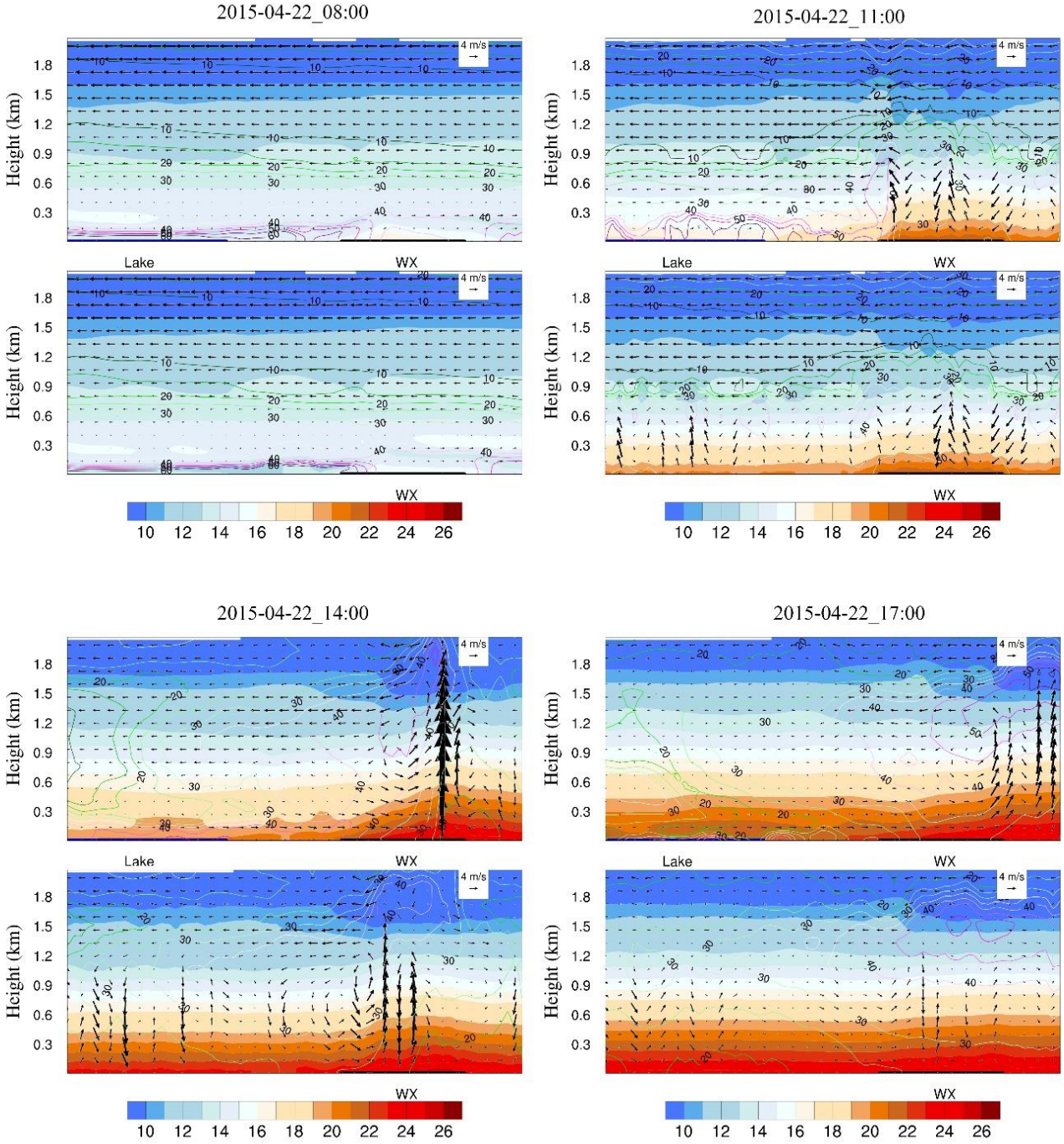


Fig 10. Same as Fig 9

- The Influence of Taihu Lake on Urban Heat Island

Nov.

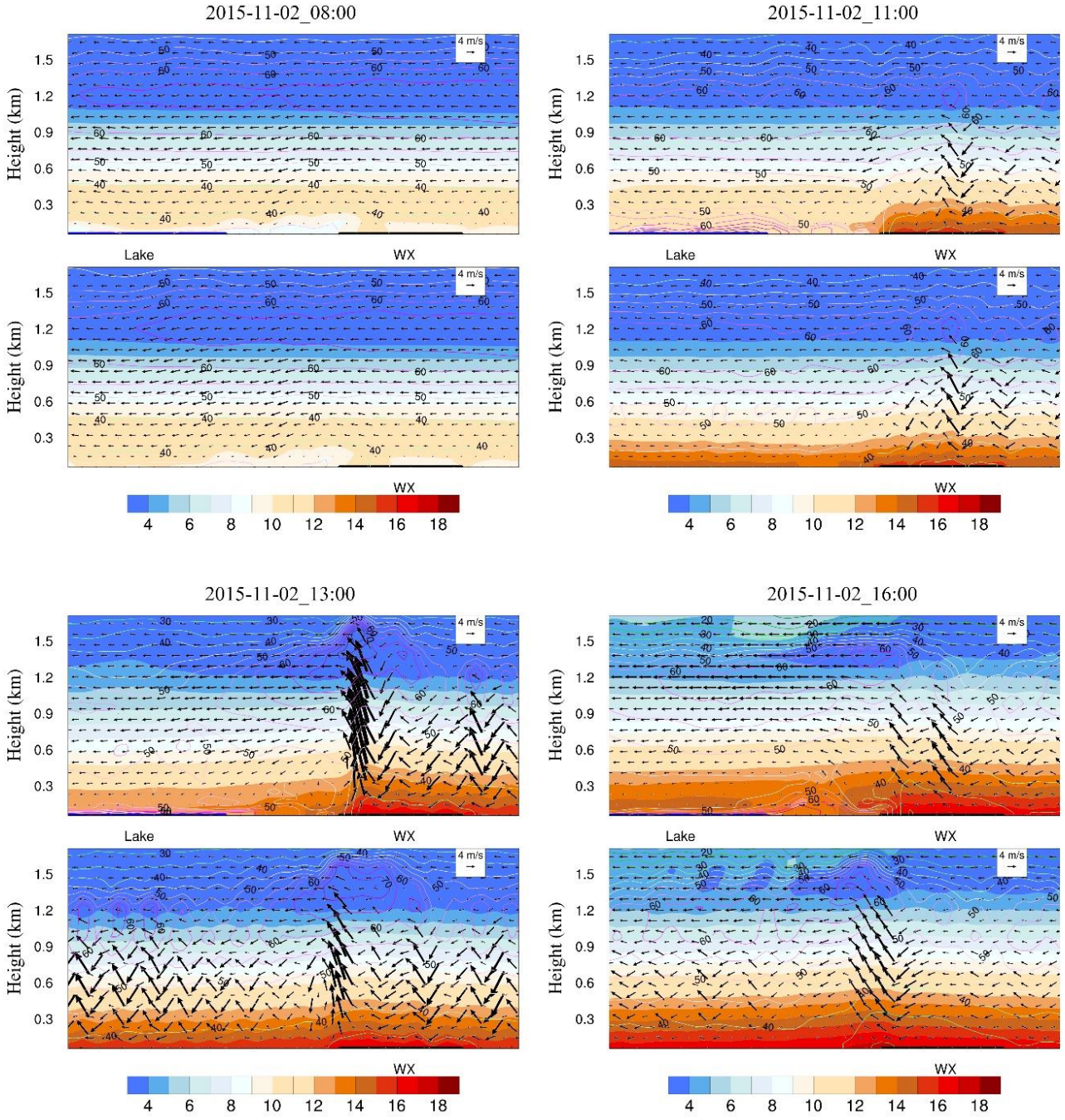


Fig 11. Same as Fig 9

- The Influence of Taihu Lake on Urban Heat Island

Jan.

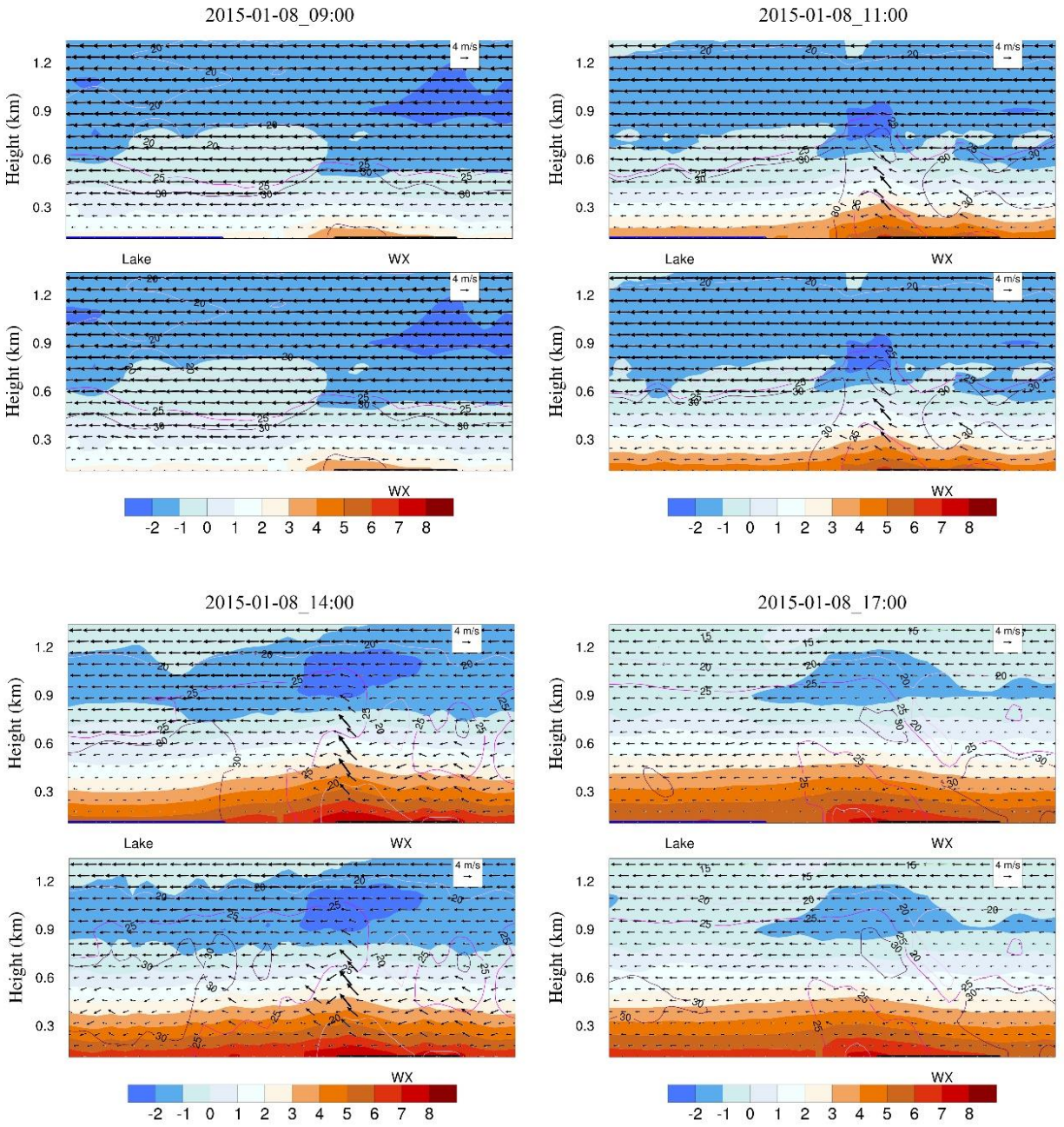
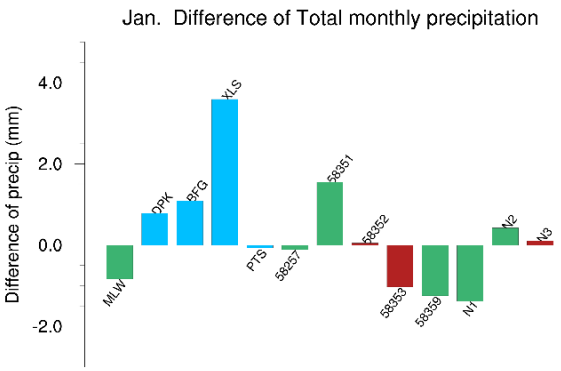
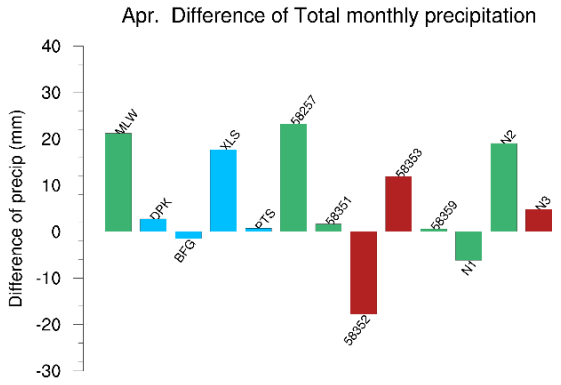
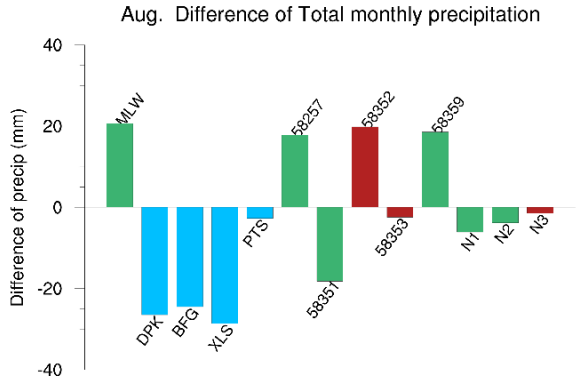


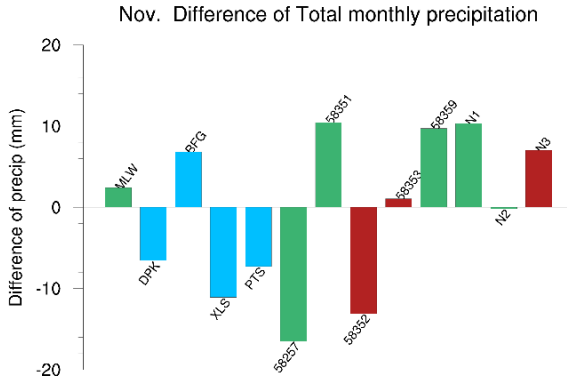
Fig12. Same as Fig 9

The Impact of Taihu Lake on Local Rainfall









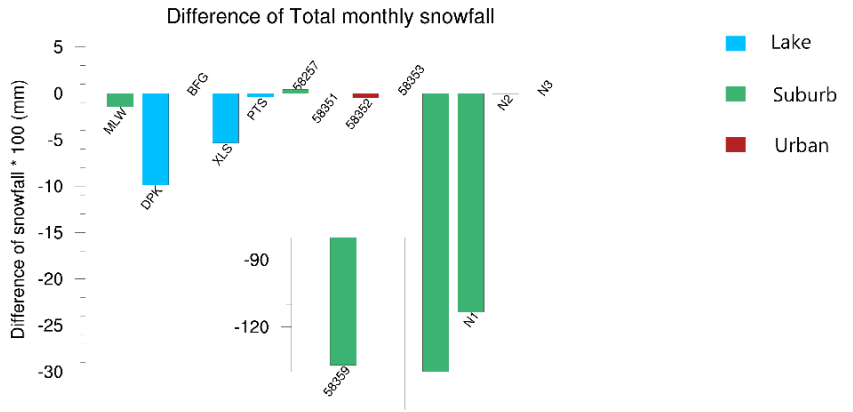
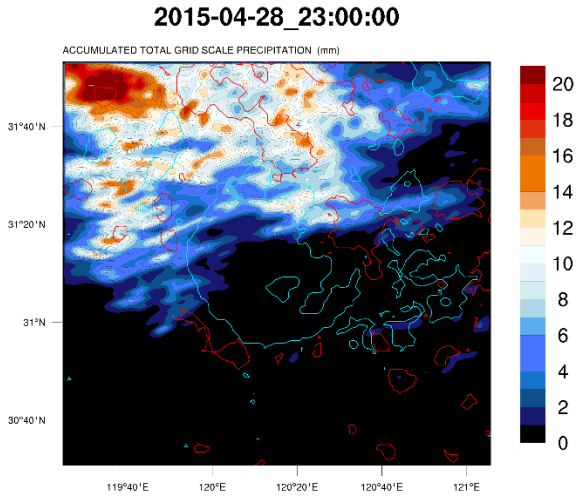


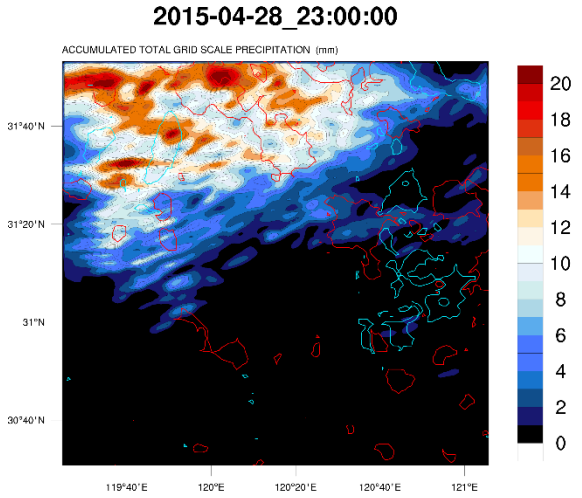
Fig 13. Differences between Lake example and Nolake example in Total rainfall for each site in January, July, and November, and the Differences between Lake example and Nolake example in total amount of snowfall in January, where blue represents the lake site, green represents the suburban site, and red represents the city site。

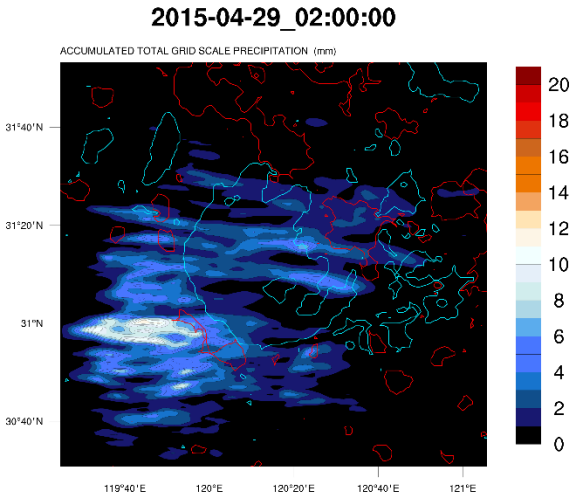
- The Impact of Taihu Lake on Local Rainfall

Lake

Nolake







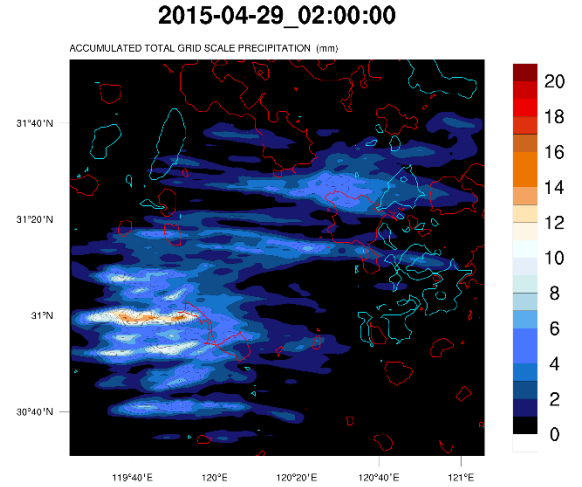


Fig 14. April 28-29 by 3h rainfall distribution map; left on the Lake example, the right for the Nolake example

Summary and conclusions

- Compared with CLM4.5 and Noah scheme, the simulated surface temperature of CLM4-LISSS scheme can reflect the change of real temperature, and the simulation of 2m air temperature and 10m wind speed is closer to the observation value.
- Taihu Lake has a significant impact on the thermal environment of the surrounding cities. In the spring and summer, Taihu Lake makes the ground temperature drop, lake circulation can break down the urban area of the heat island circulation structure, change the near ground heat and water vapor distribution, inhibit the vertical development of urban heat island. In the autumn and winter, Taihu Lake on the ground cooling effect is weak, the lake wind circulation scale smaller. Taihu Lake has little effect on the temperature and water vapor distribution in the boundary layer.
- In this experiment, the lake effect of Taihu Lake has little effect on local precipitation

Next work

- In this experiment, the CLM4-LISSS, CLM4.5 and Noah schemes were evaluated using only the August observation data due to the long simulation of the study. In the later study, the simulation time was increased, and the simulation results of three kinds of land surface processes were evaluated for the meteorological conditions in the Taihu Lake area.
- In the next step, the effect of Taihu Lake lakes on the diffusion of pollutants will be analyzed by combining the air pollution prediction model.

Thank you