

*Atmosphere*

Supporting Information for

Mesoscale and Large-Eddy Simulation of the Boundary Layer Process of Cumulus Development over Naqu, Tibetan Plateau

Part A: Comparison Between Simulation and Observation

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1. Introduction

In the WRF modeling framework, the choice of the model parameterization scheme and the lateral boundary conditions are the most important aspects to consider for the model set up . Unfortunately, choosing the best configuration parameters or boundary conditions is also the most difficult step in the model setup procedure because there is no "best fit"; It depends on the research question, location, size, or resolution of the model domain. Even after reviewing these options, some combinations of parameters or the boundary conditions being considered may still not be clear. In our analysis, we encountered two polemics and one issue. Firstly, it is well known that using high-resolution terrain data contributes to accurate simulation results of the boundary-layer processes of cumulus development. However, we found no improvement in our test simulation with the high-resolution Shuttle Radar Topography Mission (SRTM) dataset, 3 arc-second () compared with the simulation that used the traditional United States Geological Survey dataset (USGS). Secondly, we performed a test simulation by increasing the number of the vertical levels within the ABL to emphasize the effects of the external forcing on the ABL process of the CCs development and there was also no improvement. Lastly, Kain, (2004) (hereafter referred to as KF) proposed a scheme for cumulus convection which was tested over , respectively. This was because it is not certain that KF scheme can provide an expected results when applied to these domains. The objective of this section is to provide detail explanation on the problem encountered on the three key point mentioned above. The next part is organized as follows: section 2 presents the test simulation with SRTM dataset, we give details on the effect on increasing the vertical resolution within the ABL in section 2. Section 4 provided the picture of the test simulation using KF scheme in the grey zone and LES. The conclusion is presented in section 5.

1. Comparison between WRF-LES Modeling with SRTM and USGS datasets

The purpose of this section is three-fold. Firstly, it gives details on the difference between WRF-LES modeling using USGS and the same modeling but using SRTM dataset. Secondly, gives explanation on why increasing vertical resolution higher than our model configuration is not beneficial. Lastly, this section reveals that large-scale forcing was more important during the ABL processes of cumulus development on July 19, 2014.

In this section the experimental design shown in Table 1 for the WRF-LES modeling is the same as the one described in subsection 2.2.4.) of the main manuscript. The difference between the current experimental design and the one in the main manuscript is that the scenario B1 in the main manuscript is here referred to the scenario B2. The model domain configuration here labelled case B1 used 56 full sigma levels that are generated automatically from the model with the height of the first model layer at 64 m above ground level. Scenario B1 has 17 vertical layers below 4 km height AGL.

The results of the simulated pattern reflectivity for all scenarios from the experiments shown in Table 1 are presented in Figure 1, where the simulation results are compared with the observed pattern reflectivity (Figure 1a). The intercomparison of the results between the WRF-LES modeling with SRTM dataset and this with USGS shows that the results are much improved with the USGS dataset when compared to the observed.

For scenario B, performed with the SRTM dataset, the pattern reflectivity (Figure 1c) looks similar to the observed (Figure 1a), while the scenario B performed with USGS dataset has enhanced reflectivity (Figure 1c) as compared to the observed. By contrast, increasing the vertical resolution (Figures 1d,e) was not beneficial in both USGS and SRTM datasets. Especially, when the vertical levels are increased within the ABL. As shown in Figures 1d,e, the pattern reflectivity from scenarios B1 and B2 are not consistent with the observed. In addition, the atmosphere looks particularly dry in the simulation performed with the SRTM dataset. On the other hands, Figure 1e reveals that the effects of the external forcing on the ABL processes is not the main factor of the cumulus development at Naqu site. This is because increasing the number of the model layer within the ABL emphasize the effect of the external forcing on the ABL processes.

For the LES run, scenario C performed with USGS (Figure 1f) the pattern reflectivity has taken shape and consistent with the observed than the scenario C performed with SRTM dataset. By contrast, scenario C, performed with SRTM dataset (Figure 1f) presented a dry atmosphere. The results from the scenarios D and E (Figures 1g,h) have similar results between USGS and SRTM. Noted that these results were vividly repeated on the old Tianhe’s high-performance computing (HPC) system located in Tianjin, China, and tested on the Sugon HPC system from the State Key Laboratory of Disaster Prevention and Reduction for Power Grid Transmission and Distribution Equipment (SKL) at Changsha, China and later on the HPC system from Nanjing University of Information Science and Technology, Nanjing 210044, China. The results were still similar.

1. Details on the comparison between Fengyun’s Images and Scenarios C and D

From the Figure 4e and Figure 5e, depicted at 200hPa level the section 3.3. and 3.4. of the manuscript scored the results of the scenario C as the best simulation results as compared to the observation. However, one may still think that scenario D is the best one. Here again we compared the pattern reflectivity from scenarios C and D (Figure 2e) with the Fengyun’s 2D satellite images (Figure 2a,b). We can see that scenario C presented the best fit with the observation at 200 hPa level (Figure 2e). The pattern reflectivity from scenario D is not consistent with the observation.

1. Issue with the test simulation with KF scheme within the grey zone

Kain, (2004) (hereafter referred to as KF) proposed a deep and shallow CC convection scheme, which was selected to resolve CC processes only in domain . In this study the KF scheme was useless for , respectively. This is because it is not certain that KF scheme can provide an expected results when applied to these domains. are the range of grid resolutions where certain processes being neither sub-grid nor resolved, the so-called “grey zone” or “terra incognita”. Our test simulation with the KF scheme in provided too much precipitation. Figure 3 shows the results of large-eddy simulation run with KF from scenario C and D, respectively.

1. Figures 1 to 3

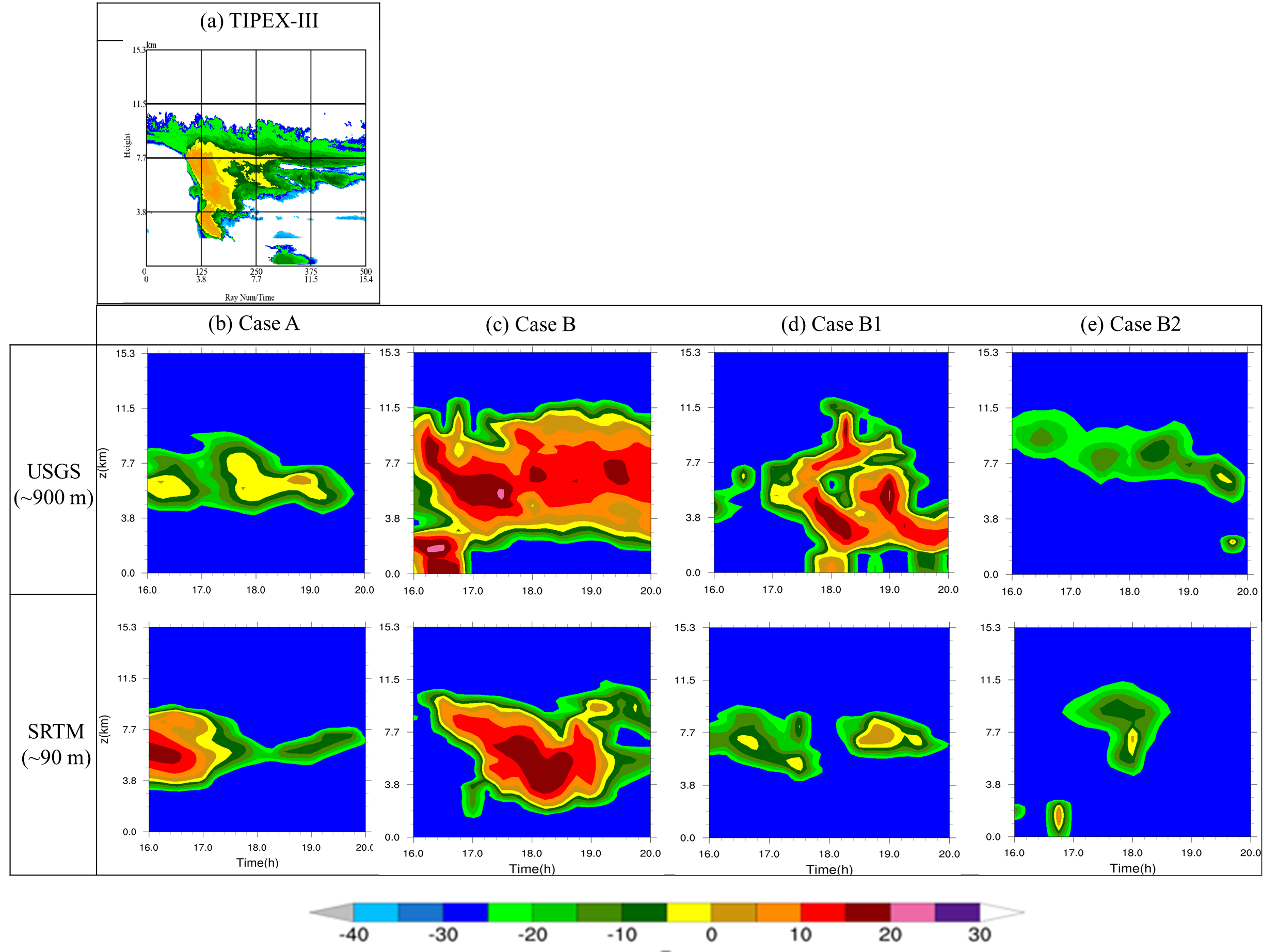
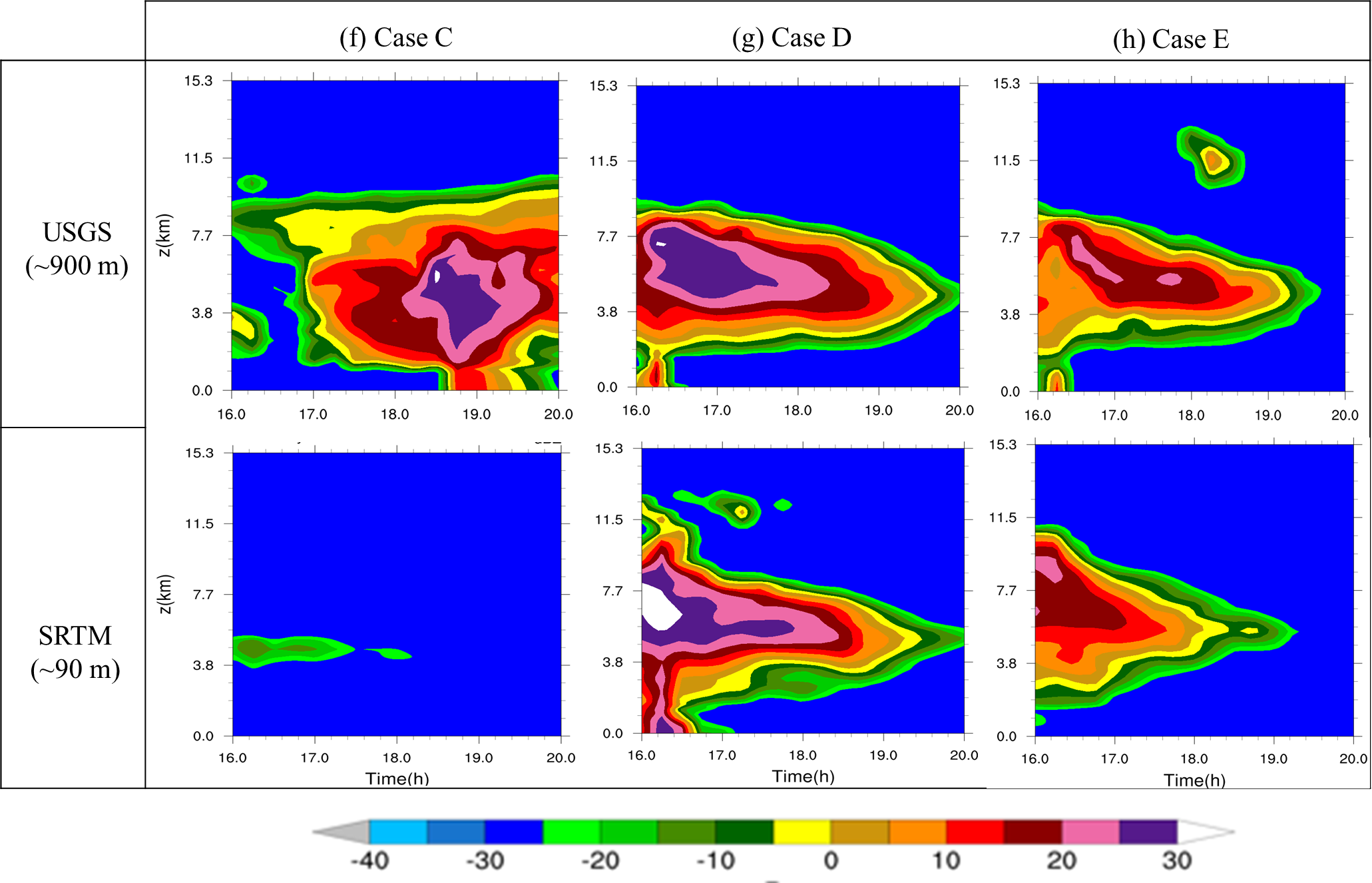


Figure 1. Vertical cross-section of pattern reflectivity on July 19, 2014: (a) Observed radar reflectivity from TIPEX-III between 18:45 and 20:00 local standard time (LST); (b-e) Comparison between United States Geological Survey 30 arc s (USGS: ~900) and Shuttle Radar Topography Mission 3 arc s dataset (SRTM;~90 m) high-resolution topographic dataset for scenarios A, B, B1 and B2, all depicted from , depicted between 16:00 LST and 20:00 LST; (f-h) same as previous but for scenarios C, D, and E, all depicted from (continued on next page).



**Figure 1.** (continued)

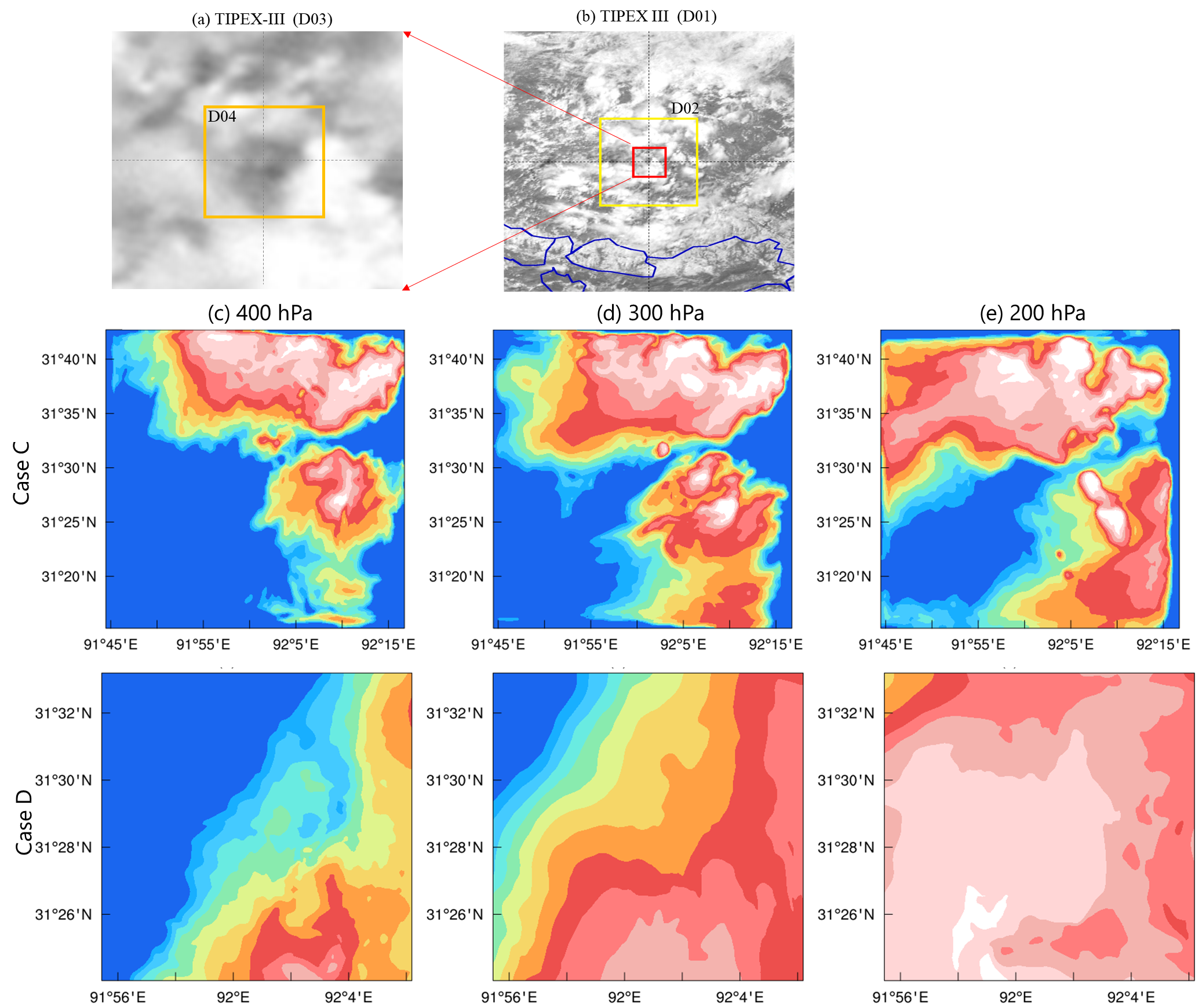


Figure 2. Comparison between pattern reflectivity from of scenarios C and D, and Fengyun’s 2D satellite images; the black arrow indicates Figure 2e from scenario C as the best simulation result.

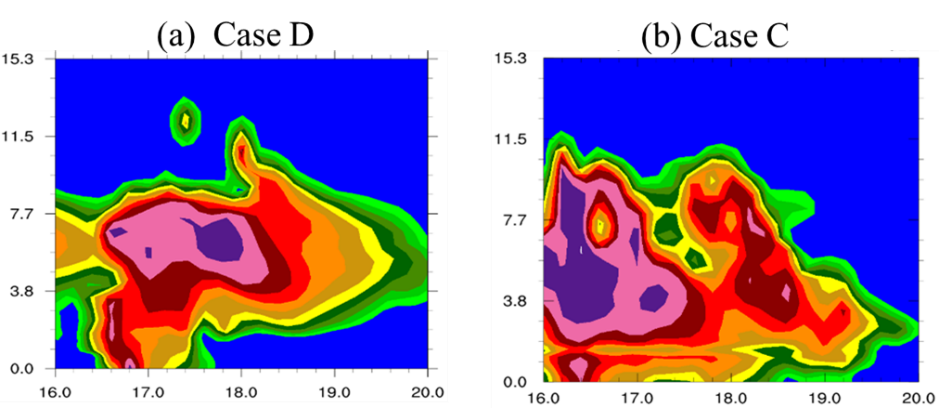


Figure 3. Same as scenario C and D shown in Table 4 and Figures 4e,f of the manuscript but here the WRF-LES was performed with KF scheme.

1. Table 1. Same as the Table 4 in the main manuscript but here the scenario B1, described section 2.2.4.) in the main manuscript is labeled here to scenario B2, while the scenario B1 in this table is added for details explanation.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Mesoscale**  **Simulations** | **Case** | **Input Data** | **Horizontal**  **Turbulence** | **Eta levels** | **Horizontal Grid Spacing and** | | |
| 9,234 m | 3,078 m | 1,026 m |
| A | FNL | TKE1.5 | 50, 1rst model  level: 65 m with | is useless | is useless | is useless |
| B | FNL,  Obs. | = 980,000 m | = 330,000 m | = 120,000 m |
| B1 | 56, 1rs model level: 64m with  17 layers  <4km |
| B2 | 56, 1rst model level: 8 m with |
| **Microscale**  **Simulations** | **Case** | **Input Data** | | **Parent**  **Mesoscale**  **Turbulence**  **Model** | **SGS**  **Turbulence**  **Model** | **Horizontal Grid Spacing**  **and** | |
| 342 m | 114 m |
| C | Input  from case B, FNL, and  observation | | TKE1.5 | TKE1.5 | = 40,000 m | = 15,000 m |
| D | Observation and FNL | | The parent mesoscale turbulence model (TKE1.5) is useless |
| E | FNL | |

1. Experimental Data and Lateral boundary conditions

The experimental data are described in details in section 2.1.) of the manuscript.

All data used for the Lateral boundary condition are described in details in section 2.2.2.) of the manuscript. The analysis used the model outputs.