Numerical simulation of the heavy rainfall at the north Osaka Plain

M. Terada and T. Satomura
Division of Earth and Planetary Sciences, Graduate School of Science, Kyoto University,
Kitashirakawa Oiwakecho, Sakyo, Kyoto, 606-8502, Japan
e-mail: satoomura@kugi.kyoto-u.ac.jp

ABSTRACT

A localized heavy rain occurred at Itami in the northern Osaka plane on September 6, 1994. To understand its generation, maintenance and developing mechanisms and effects of topography around the Osaka Plane on the heavy rain, numerical experiments using WRF is completed.This heavy rain started about on 21 LST September 6, 1994, and ceased around on 05 LST September 7, 1994, before passing a cold front. The accumulated rain exceeded 300 mm during 12 hours, while the area exceeding 100 mm was closely packed.

To simulated the localized rain, we used the non-hydrostatic regional model, WRF, and nested domain configuration. The coarser domain covers whole Japan with horizontal grid increment of 10 km, and the finer domain covers small area including the area of torrential rain with 2 km grid increment. The control experiment represented the localized heavy rain are rather well. Sensitivity tests of effects of topography, especially effects of Rokko Mountain, and effects of thermodynamical stratification suggest the following mechanisms of this localized heavy rain:

1) High equivalent potential temperature air flew from the south through the Kii Channel, approached to the Rokko Mountain, orographically lifted and made convective cells.

2) The convective cells drifted to the east-north-eastward by the middle to upper troposphere wind.

3) During the drifting, the convective cells were supplied with high equivalent potential air by lower southerly wind and, thus, the cells further developed.

4) The lee area of the Rokko Mountain for the middle to upper troposphere wind suffered by the localized intermittent strong rain.

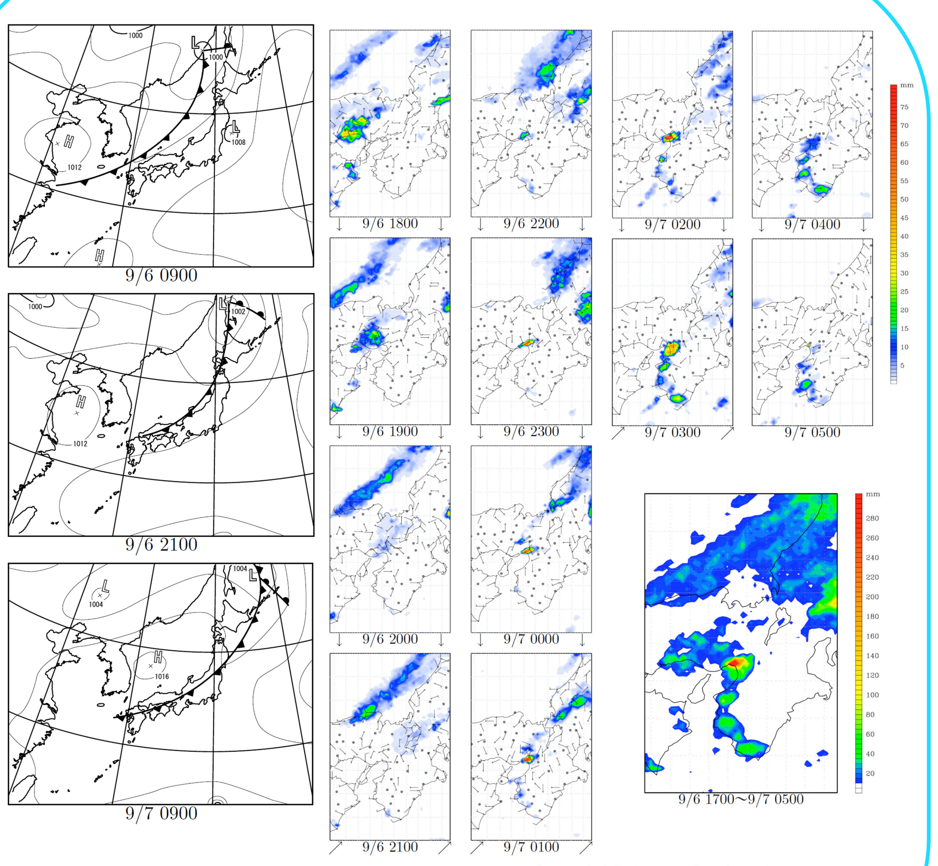

Fig. 1. Weather maps (left), observed hourly rainfall (right) and total rainfall (right bottom).

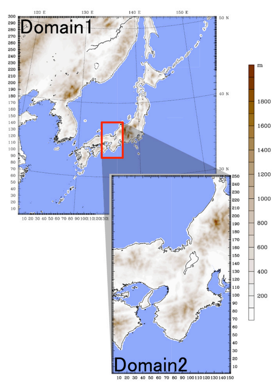

Fig. 2. Domains.

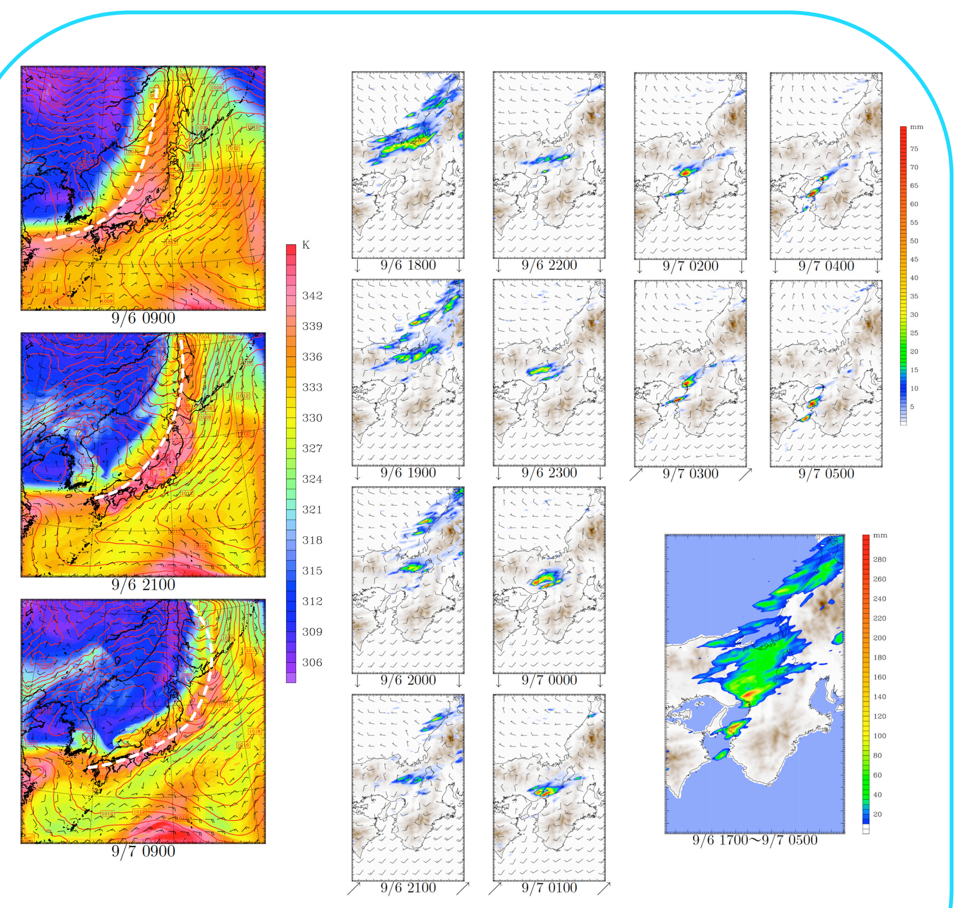

Fig. 3. Simulated weather maps (left), hourly rainfall (right) and total rainfall (right bottom).

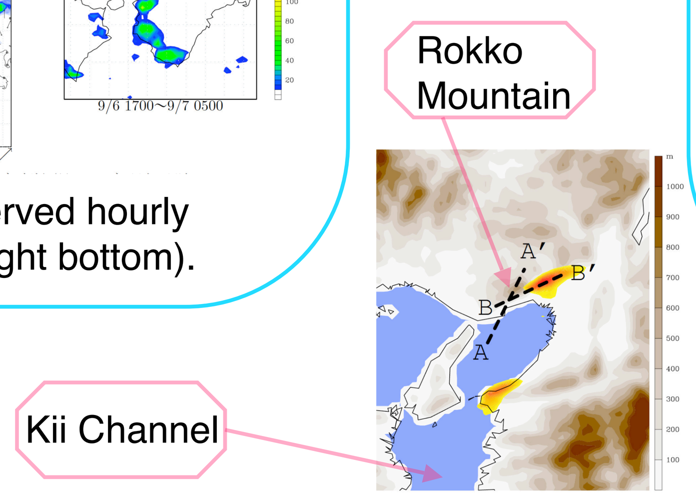

Fig. 4. Simulated 12 hour accumulated precipitation and cross cutting lines.

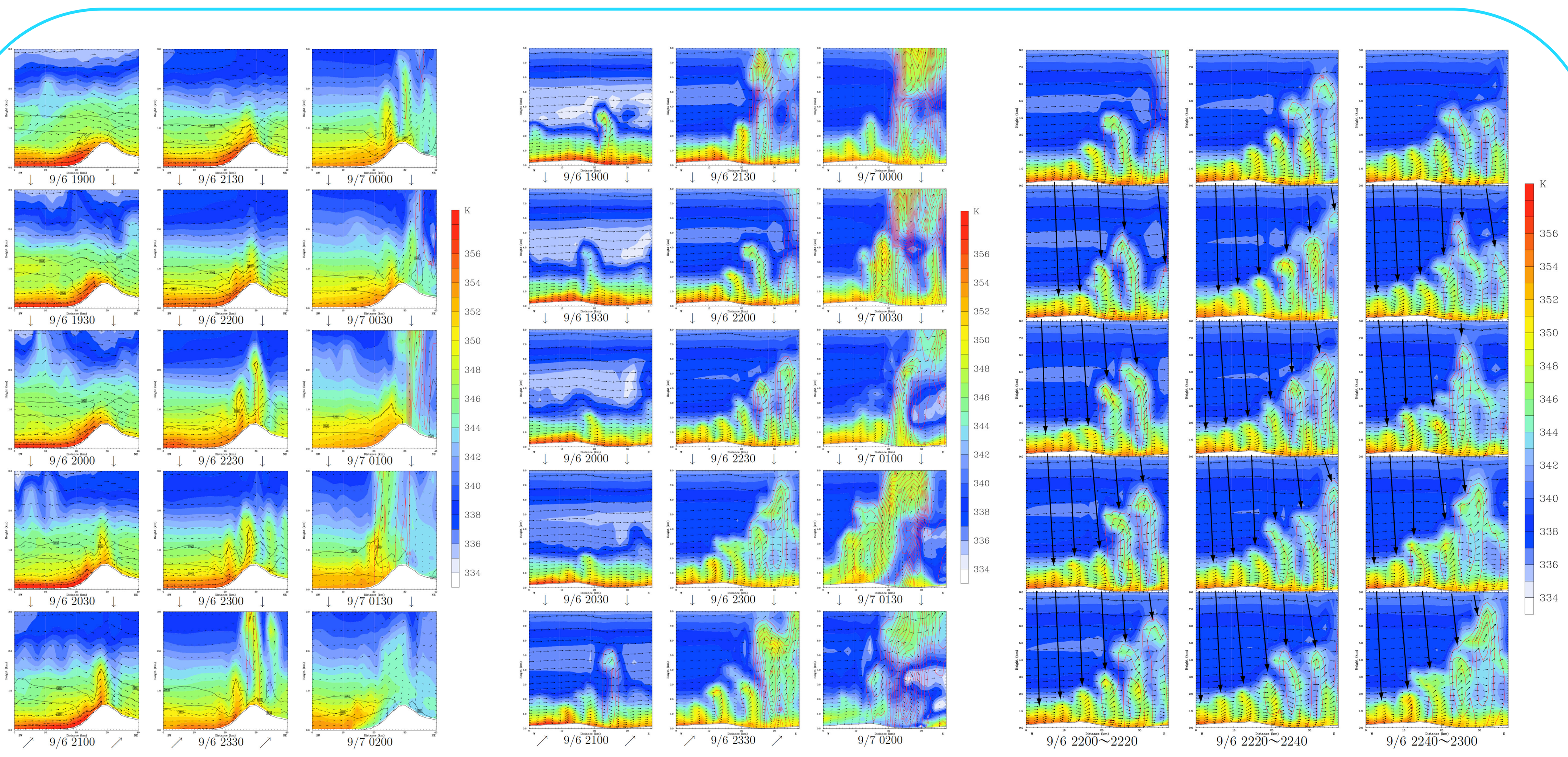

Fig. 5. Vertical cross section along A-A' (left) and B-B' (middle and right). Color is θ_e, red lines are precipitation hydrometeor (0.5 g/kg). Black solid lines and dashed lines in left panel are θ_{es} and θ_e.

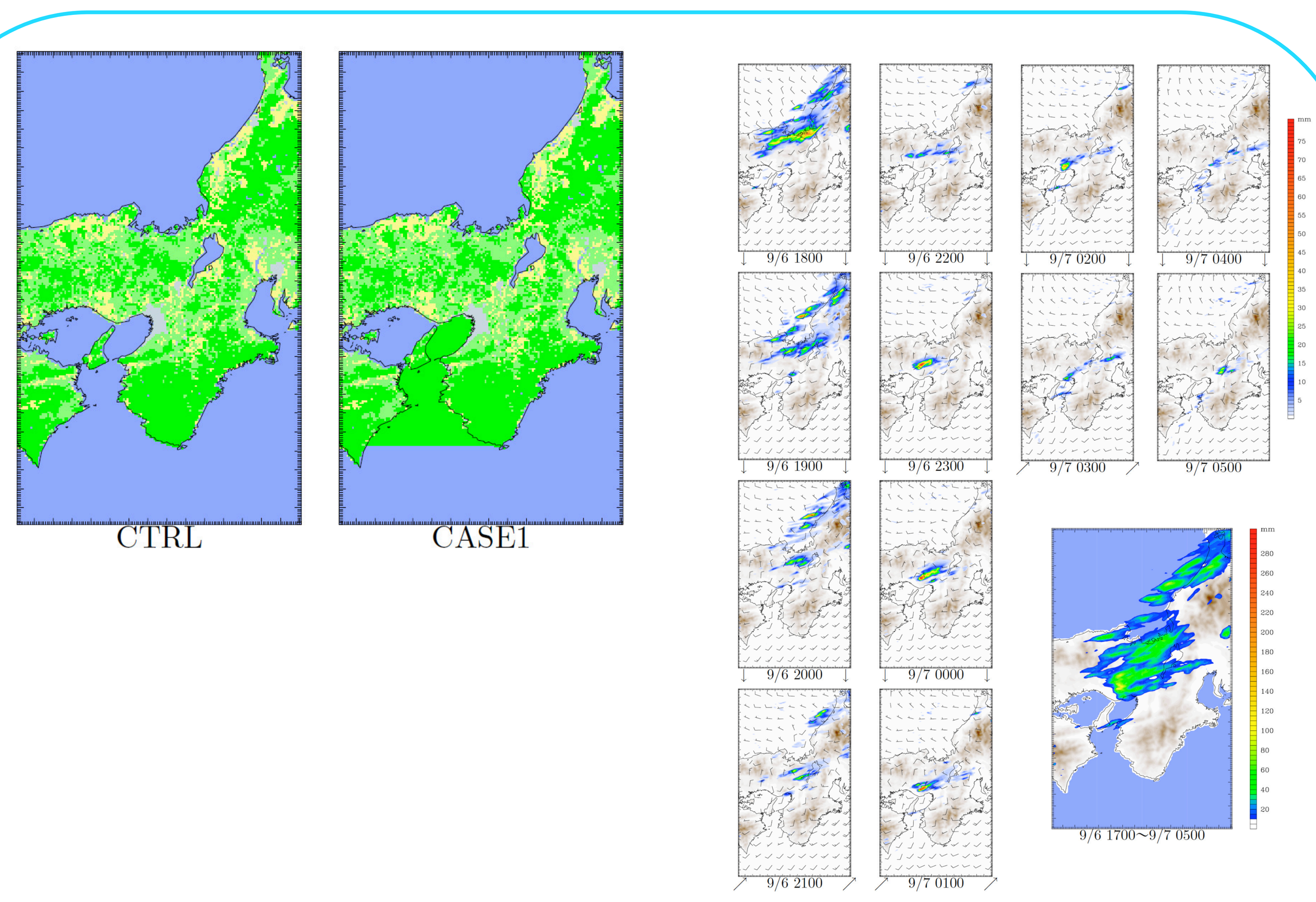

Fig. 6. Case 1. Left: Kii Channel is changed to forest. Right: Hourly rainfall (right) and total rainfall (right bottom).

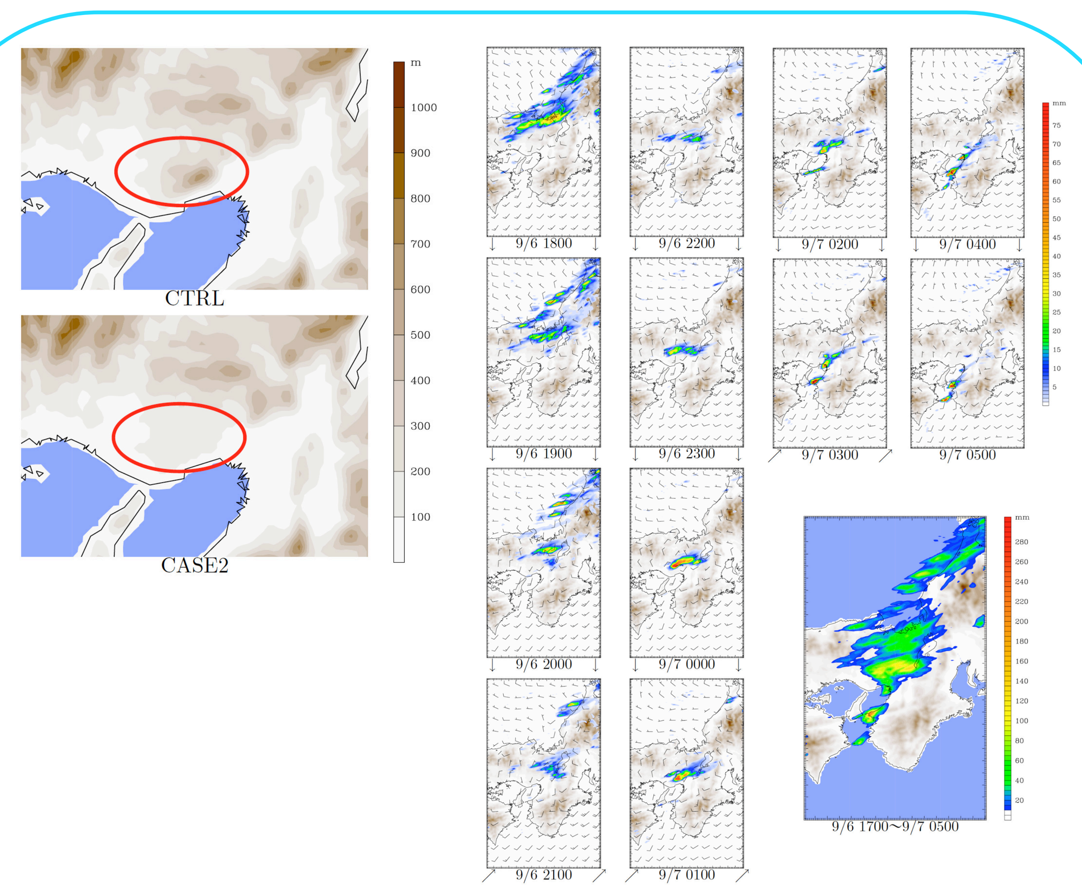

Fig. 7. Case 2. Left: Rokko Mountain is removed. Right: Hourly rainfall (right) and total rainfall (right bottom).

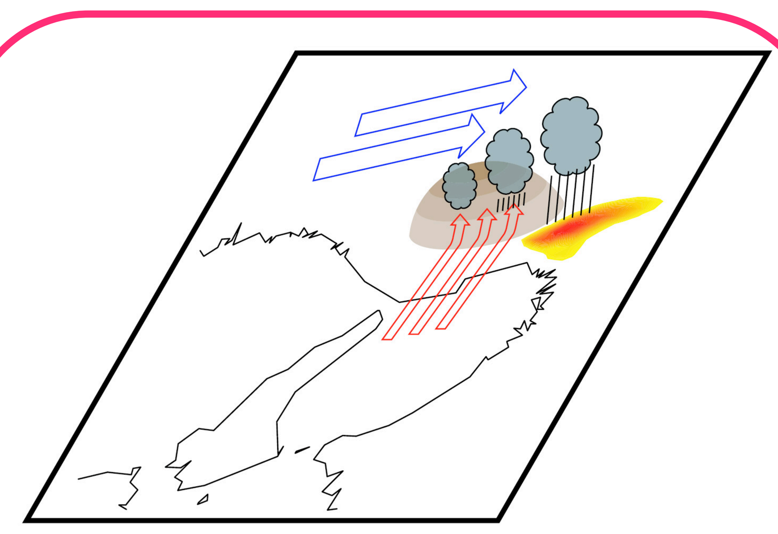

Fig. 8. Schematic figure on the mechanism of torrential rain at the lee of Rokko Mountain.

1. The Torrential Rain Event (Fig. 1)

From 21 JST (Japan standard time; UTC + 7 hours) on 6 September 1994 to 05 JST, torrential rain event occurred in the northern part of Osaka Plain when a cold front approached Japan. The maximum total precipitation was 266 mm, and the heavy rainfall was concentrated only in about 20 X 10 km area. More than 9,000 houses were flooded.

2. Model (Fig. 2)

We used the WRF (AR-WRF v.2) in two domains nested by one-way with δx = 10 km (domain 1) and 2 km (domain 2), respectively (Fig. 2). In the vertical, 31 layers were used. Only in the domain 1, K-F cumulus parameterization was employed. The cloud microphysics scheme of the Lin type was included in both domains. The initial and boundary conditions for domain 1 were given by NCEP/NCAR Reanalysis.

3. Results

3.1 Check

- Figure 3 shows that the model reproduces the synoptic cold front and the narrow heavy rain area well.

3.2 Structure

- Fig. 4 left: Vertical cross section along the line A-A' in Fig. 4 indicates that high θ_e air coming from SW was lifted on the slope of Rokko Mountain.
- Fig. 4 middle and right: Vertical cross section along the line B-B' indicates that convective clouds triggered at the Rokko Mountain continued developing during their moving towards east.

3.3 Sensitivity tests

- Case 1: Kii Channel is changed to forest (Fig. 6) Concentrated heavy rainfall was disappeared. Deep mixed layer developed over "new" land diluted the high θ_e air from SW (not shown).
- Case 2: Rokko Mountain is removed (Fig. 7) Concentrated heavy rainfall was disappeared.

4. Conclusion (Fig. 8)

1)High θ_e air flew from the south through the Kii Channel, approached to the Rokko Mountain, orographically lifted and made convective cells.

2) The convective cells drifted to the east-north-eastward by the middle to upper troposphere wind.