Tibetan Plateau's snow accumulation estimated from regional climate model simulation

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Abstract

To investigate the hydrological cycle of Asian region, we developed a regional climate model coupled with a simple snow model and integrated it for 10 years continuously, nested into a general circulation model. The accumulation mechanism of snow around Tibetan Plateau is investigated using that model. At the south-eastern part of the plateau, the main source of snow is the summer monsoon precipitation. However, around the western part, we have another precipitation maximum, caused by the western disturbances evolving in early spring. These characteristics have good correspondence to the field studies.

1. Introduction

The largest gross area of the mountain glaciers in the northern hemisphere mid-latitude is found around the Tibetan Plateau. Many studies have been performed to clarify the growth mechanism of glaciers in that region. From observational studies, it is said that the glaciers around the south eastern edge of the Plateau grow with the precipitation of the Asian summer monsoon. On the other hand, around the western part of the Plateau, the glaciers grow with the precipitation associated with the western disturbances developed in the early spring. However, there still exists no climatic study by using the numerical model.

The research using Regional Climate Models (RCMs) is one of the dynamical downscaling method, and expected to represent the distribution of the mesoscale precipitation which cannot be represented with ordinary General Circulation Models (GCMs). Especially we can improve the orographical precipitation by using higher resolution models, because it mainly depends on the resolution of the mountain range. Especially we can expect the advantage of using RCMs in forecasting snow accumulation.

Many studies have applied RCMs to snow accumulation in the arctic region. Lynch et al. (1998) drove a RCM coupled with several kinds of land surface schemes, and pointed out the importance of snow albedo, in the snow melting process. Dethloff et al. (2002) and Box and Rinke (2002) investigated the formation mechanism of Greenland ice sheet. Because ice sheet is an integral value of precipitation minus evaporation, it diminishes the error coming from short term fluctuation. They succeeded to explain the distribution of ice sheet in Greenland, using seasonal forecast of RCMs.

In this study, we try to investigate the mechanism of snow accumulation around Tibetan Plateau, by using MRI-RCM driven by MRI-CGCM2.2.

2. Models and experiments

Here we use Meteorological Research Institute's Regional Climate Model (MRI-RCM) (Murazaki et al., 2002). The horizontal grid spacing is 60km, and it has 36 levels in the vertical direction. The area covers Indian subcontinent, Tibetan plateau, Indochina peninsular, and Japan Islands. Fig.1 shows the topography of the model only around the Tibetan Plateau. The RCM is integrated continuously for 10 years, nested in MRI-CGCM2.2 (Yukimoto et al., 2001) by using Spectral Boundary Method (SBC) (Sasaki et al., 1995). Rajendran et al. (2004) showed that MRI-CGCM2.2 successfully reproduced the climate around the south and east Asian monsoon region.

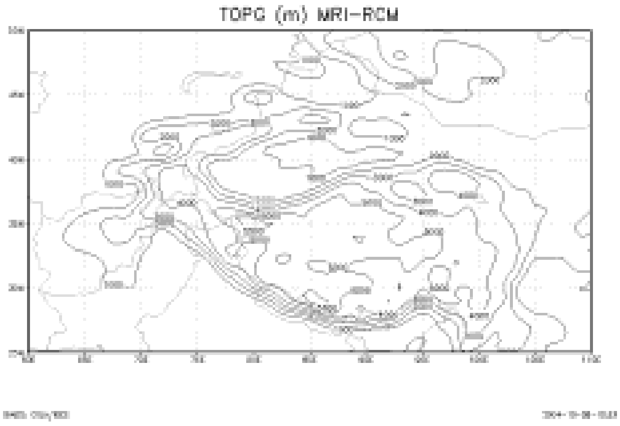

Fig.1: Topography of MRI-RCM (m). Only around the Tibetan Plateau is indicated.

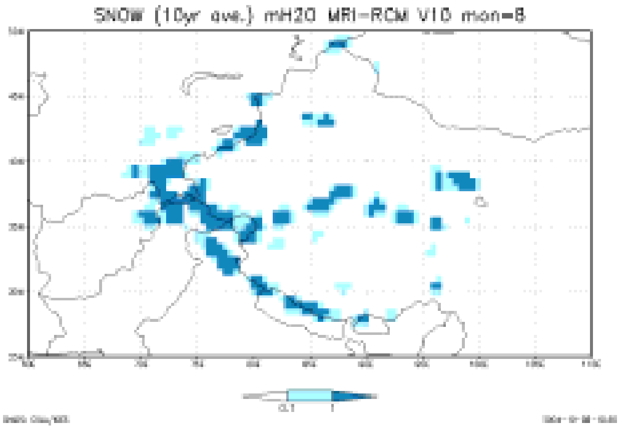

Fig.2: Snow equivalent water content (mH2O) of MRI-RCM. 10 years average of August.

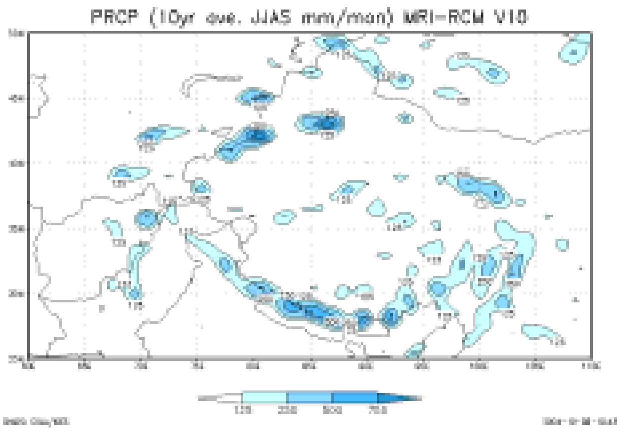

Fig.3: Surface precipitation of MRI-RCM. Mean value of JJAS of 10 years, in mm/mon.

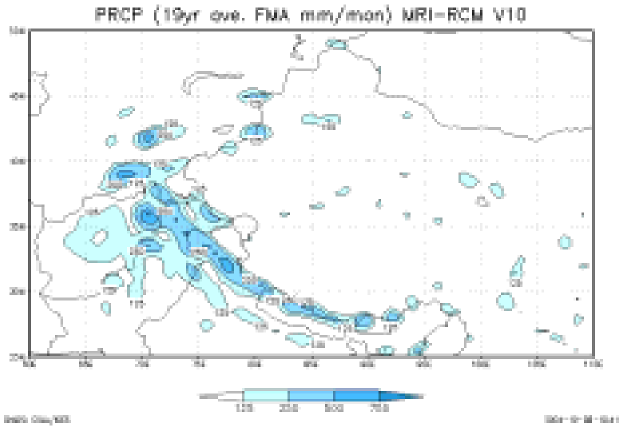

Fig.4: Same as in Fig.3 but for FMA.

3. Land Surface model coupled with MRI-RCM

We developed a new land surface scheme and coupled it with the MRI-RCM for long term integration. The land surface scheme solves (1) the land surface heat budget using the 1st soil layer (4cm deep), (2) the heat conduction equation to get the soil temperature and (3) diffusion equation (the Darcy's law) to get the soil water content. We adopt the code of SSiB (Xue et al., 1991) for (3).

As described in Takayabu (2001), there are many types of numerical model of snow accumulation and melting processes. Here, the temperature of the model lowest layer is used to decide if the precipitation is snow or rain. The snow begins to accumulate after the 1st soil layer saturates with water. The degree day method is applied in the model. The heat capacity of the model is not conserved, because the snow does not melt through the downward shortwave radiation. Originally the degree day method uses the daily average temperature to melt the snow. In the model, we use the temperature at every time step. The density of the snow is assumed to be 0.4g/cm^3, and the snow melting speed is set 5.5mm/deg/day. These values are the typical ones, adopted in the original degree day method model. The melt water infiltrates into the soil. The physical characteristics of the soil are changed to the values of snow, while the soil surface is buried under the snow.

The soil water stops to move while the soil temperature is below the freezing temperature. However, the evaporation from the snow surface is counted. The evaporation stops when there is no snow on the ground surface. We increase the heat capacity of the soil when the soil water freezes or the frozen soil melt, to include the effect of water freeze or ice melt.

4. Results

4.1. The glaciers represented in the model

In the model we don't parameterize the glacier. So, the eternal snow piles up at the same grid point. Therefore, we can take the heavy snow accumulated region for the glacier. Fig.2 indicates mean snow equivalent water (in mH2O) of the warmest month (August). We decide the grid points with snow over 1mH2O area as glaciers in the model. When we compare with the topography of the model (Fig.1), we can find glaciers over almost all the mountain ranges. This has good correspondence with the existing glaciers, as shown in Shi (1980).

4.2. The growth of glaciers

Fig. 3 indicates the monthly mean precipitation of the Asian summer monsoon season (from June to September). Compare the figure with Fig.2, we can find that all glaciers to the east of 75E correspond to the area of much precipitation of this season. This suggests that all the glaciers of that area grow through the summer monsoon sesons precipitation.

Fig. 4 indicates the monthly mean precipitation from February to April. This figure shows us that the glaciers over Hindu Kush Mountains and Pamir Hights grow with the precipitation in this season. As shown by Lang and Barros (2004), the western disturbances approach these regions several times in this season, and the precipitation comes from the passage of these disturbances.

5. Conclusion

To investigate the hydrological cycle of Asian region, we developed a regional climate model and integrated it for 10 years continuously, nested into a general circulation model. A simple snow model is added into the regional climate model, and we succeed to reproduce the seasonal change of the snow cover area over Asian region realistically. The accumulation mechanism around Tibetan Plateau is investigated using that regional climate model. At the southern periphery of the plateau, the main source of snow is the summer monsoon precipitation. However, around the western periphery, we have another precipitation maximum, caused by the western disturbances evolving in March. These characteristics have good correspondence to the field studies.

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References

Box, J. E. and A. Rinke, 2003: Evaluation of Greenland ice sheet surface climate in the HIRHAM regional climate model using automatic weather station data. J. Climate, 16, 1302-1319.

Dethoff, K., M. Schwager, J. H. Christensen, S. Kilsholm, A. Rinke, W. Doen, F. Jung-Rohtenhaeusler, H. Fisher, S. Kipfstuhl and H. Miller, 2002: Recent Greenland accumulation estimated from regional climate model simulations and ice core analysis. J. Climate, 15, 2821-2832.

Lang, T. J. and A. P. Barros, 2004: Winter storms in the Central Himalayas, J. Meteor. Soc. Japan, 82, 829-844.

Lynch, A. H., D. L. McGinnis and D. A. Bailey, 1998: Snow-albedo feedback and the spring transition in a regional climate model (RegCM2), J. Geophys. Res. 105, 29565-29557.

Murazaki, K, H. Sasaki and Y. Sato, 2002: A present climate simulation using a regional climate model (in Japanese). Proc. 2002 Fall meeting of the Japan Meteorological Society, Sapporo, Japan. Japan Meteorological Society, 82.

Rajendran, K., A. Kitoh and S. Yukimoto, 2004: South and East Asian summer monsoon climate and variation in MRI coupled model (MRI-CGCM2), J. Climate, 17, 763-782.

Sasaki, H., H. Kida, T. Koide and M. Chiba, 1995: The performance of long-term integrations of a limited area model with the spectral boundary coupling method. J. Meteor. Soc. Japan, 73, 165-181.

Shi, Y., 1980: Some achievements on mountain glacier researches in China. Seppyo, 42, 215-228.

Takayabu, I., K. Takata, T. Yamazaki, K. Ueno, H. Yabuki and S. Haginoya, 2001: Comparison of the four land surface models driven by a common forcing data prepared from GAME/Tibet POP'97 products – Snow accumulation and soil freezing processes -, J. Met. Soc. Japan, 79, 535-554.

Xue, Y., P. J. Sellers, J. J. Kinter and J. Shukla, 1991: A simplified biosphere model for global climate studies, J. Climate, 4, 345-364.

Yukimoto, S., A. Noda, A. Kitoh, M. Sugi, Y. Kitamura, M. Hosaka, K. Shibata, S. Maeda and T. Uchiyama, 2001: The new Meteorological Research Institute coupled GCM (MRI-CGCM2) – Model climate and variability -. Pap. Meteor. Geophys. 51, 47-88.