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INFLUENCE OF SOIL AND VEGETATION ON RAINFALL IN COASTAL DESERT AND MOUNTAINOUS AREA

Ryohji Ohba*, Takeshi Adachi and Tomohiro Hara
Mitsubishi Nagasaki R&D Centre, Mitsubishi Heavy Industry Ltd., Nagasaki, Japan

Hiromasa Ueda
Disaster Prevention Research Institute, Kyoto University, Uji, Japan

Ronald. W. A. Hutjes, Hendrikus. W. Ter Maat, and Berney Bisselink
Alterra B.V., Wageningen University, Wageningen, Netherland

*1. INTRODUCTION

Japan Ministry of Education, Culture, Sport, Science and Technology (MEXT) started a new national research project on Co-existing of Human being, Nature and Earth, titled " Advanced Prediction System and Counter-measures of Numerical modeling and technology of Global and Regional- and Meso-scale Water Cycle (Global Water Cycle Project; GWCP)". Purpose of this project is to make a master plan for the improvement of desert environment. This project will continue from April 2002 until March 2007. Mitsubishi Heavy Industries (MHI) of main contractor organizes an interdisciplinary project team with Frontier Research System for Global Change (FRSGC), Kyoto University, Tottori University and Sophia University. Main philosophy of this project is to create a sustainable water cycle between sea, land and atmosphere in the region of "Coastal Desert", such as Asir region near the Red Sea. It is expected that results of this project will be applied to many arid area in Middle East, Africa, India, China and so on.

Total image of this project and contributions of each task team are shown in Fig. 1. Frontier Research System for Global Change (FRSGC) covers global scale analysis and modeling. Kyoto University, MHI, Wageningen University and Japan Atomic Energy Research Institute (JAERI) jointly perform regional scale modeling by MM5 and RAMS models. MHI develops sustainable system of water resources, using solar power and cloud seeding technique. Tottori University and Sophia University make a sustainable oasis network system as a residential space.

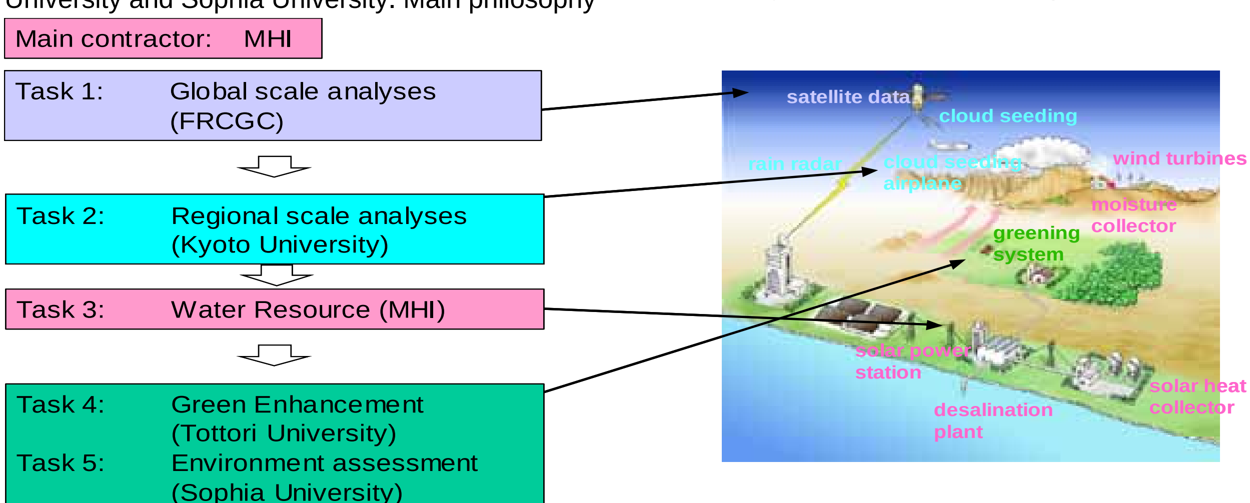


Fig. 1 Total Image of each task

*Corresponding author address: Dr. Ryohji Ohba, Nagasaki R&D Center, MHI, Fukahorimachi 5-717-1, Nagasaki, Japan.
E-mail: ryohji_ohba@mhi.co.jp

The spatial and temporal distribution of rainfall variability is crucial in determining the socioeconomic conditions in the arid regions of the world. A reliable prediction of the rainfall variability is thus an important component of a disaster mitigation system. In addition, analysis of the underlying processes of such natural variability in the regional hydrological cycle provides clues to understand the mechanism of the desertification. In the present study, we discuss the region called "Asir" in the southwestern part of the Kingdom of Saudi Arabia to understand the influence of soil and vegetable on the rainfall variability. The Asir region enjoys a relatively good seasonal rainfall in spring and winter seasons, due to the effects of topography, Mediterranean Sea and Indian Ocean.

In the present paper, we introduce some of our preliminary results based on the regional scale analyses of rainfall, using ECMWF reanalysis data and "Earth Simulator".

2. RAINFALL CLIMATOLOGY IN ARABIAN PENINSULA

The rainfall amounts in the coastal plain area (Jeddah, Gizan) are approximately 100-200 mm. The mountains (Abha, Khamis), which reach elevations up to 2000 m above sea level experiences orographic rainfall due to the topographic effects. The rainfall amounts are approximately 300 mm (fig. 3). The rainfall patterns in the study region have a strong teleconnection with ENSO and DMI (fig. 4).

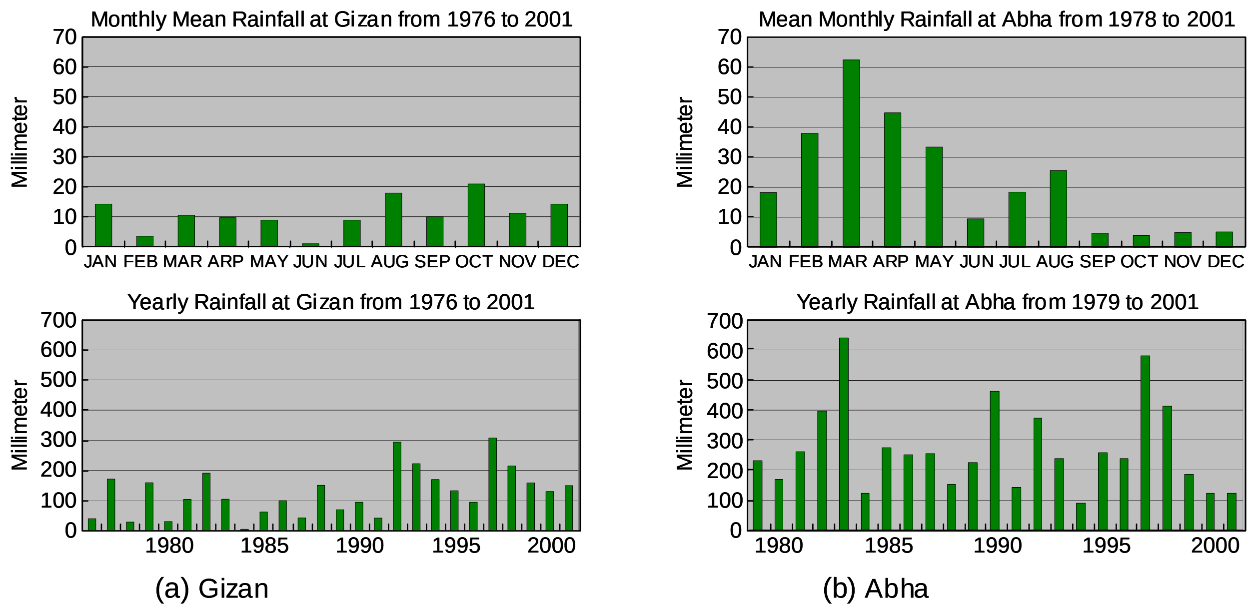


Fig. 2 Seasonal evolution of mean monthly rainfall (mm) and annual rainfall (mm) in Saudi Arabia, observed at Gizan and Abha.

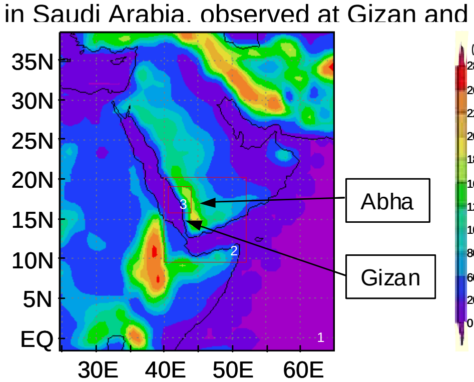


Fig. 3 Topography heights (m) for RAMS model simulations on grid 1, grid 2 and grid 3.

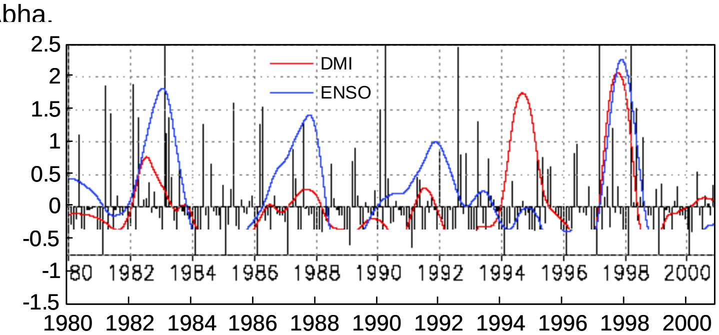


Fig. 4 Relation of rainfall anomalies in Abha with ENSO and DMI.

3. DATA, MODEL AND METHODOLOGY

RAMS simulations were performed from 0000 UTC on 21 February 2000 to 0600 UTC on 30 March 2000; the initial and boundary conditions were provided by the European Centre for Medium-Range Weather Forecasts (ECMWF) global model every 6 hours at 0.5 x 0.5 degrees spatial horizontal resolution.

A three-grid configuration has been used, as shown in Fig. 3. The largest grid covers Saudi Arabia and parts of east Africa. Horizontal grid spacing on grid 1 is 80 km. The topography on grid 1 is highly smoothed because of the coarse grid resolution. Grid 2 contains the southwestern part of the Arabian Peninsula, and parts of northeast Africa. Grid 2 has a horizontal grid spacing of 16 km. With 16 km grid spacing, the Asir mountain ranges are identifiable. Grid 3 is located over the southwest Saudi Arabia Red Sea coast including the mountain ranges. At this resolution, 4 km, the details of topography can be seen. The first level of all the three grids is 47 m.

In this study RAMS version 4.4 will be used in a nested grid configuration together. The simulations will be done on the Earth Simulator. The model options used in the "control" run version 1 (V1) are presented in table 3.1.

Table 3.1: Model options used in the "control" run version 1 (V1)

grids	1	2	3
δx, δy	80 km (60x62)	16 km (82x82)	4 km (58x58)
δt	90 sec	15 sec	7.5 sec
δz		100 - 500 m (43)	
radiation		Chen & Cotton ('83)	
land surface		LEAF-2 (Walko et al.,2000)	
diffusion		Mellor/Yamada ('82)	
forcing		ECMWF	
forcing time scale		lateral 1800 s, centre 7200 sec	
convection		Full microphysics package (Flatau, '89)	
land use		USGS (standard in RAMS 4.4)	
soil		IGBP-DIS Soil properties database (Global Soil Data Task Group,2000)	

4. VALIDATION OF RAMS MODEL

4.1 Rainfall compared with satellite images

On 16 March 2000, in the satellite image (INDOEX) a curved-shaped cloud system occured over the Arabian Sea (circle). A curve-shaped rainband is also found in the RAMS map. In the TRMM maps, small cells with rainfall were lined up in the middle of the curved-shaped cloud. (Fig. 5)

Generally RAMS rain is greater than TRMM rain. On 16 March, over Africa, a large area of rainfall can be identified within the longitudes 25 and 40oE and latitudes 2oS and 10oN. The existence of this area is consistent with the RAMS analyses. However, the TRMM map identifies more isolated convective elements than does the RAMS map. (Fig.6)

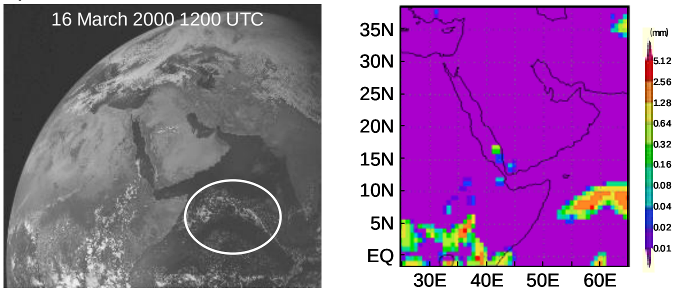


Fig. 5 INDOEX visible satellite picture compared with RAMS rainfall simulations (mm) for the same time.

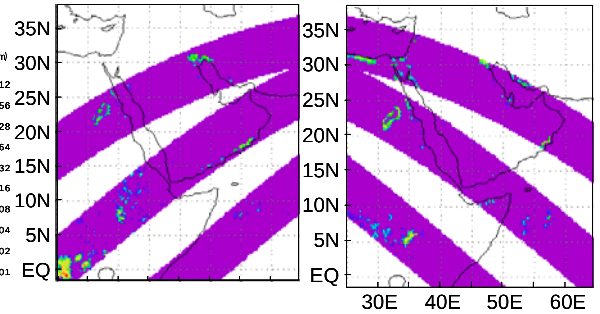


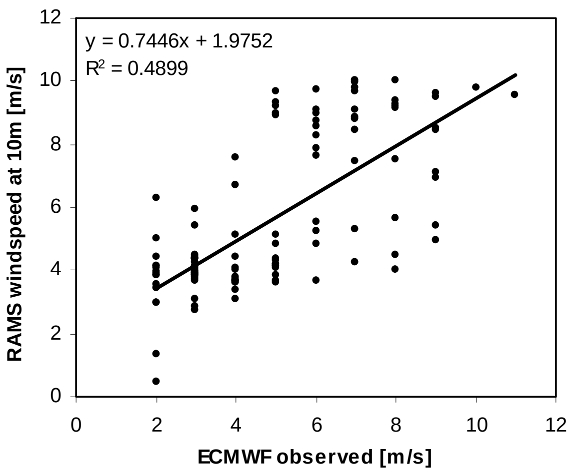
Fig. 6 surface rain rate (mm/hr) images for TRMM ascending and descending overpasses.

4.2 Comparison with surface observed data

(1) Original parameterization

The modeled results of wind speed are not in good agreement with observations, except for Abha. In Gizan even a negative correlation is observed. (Fig. 7) In general, the correlations for temperature demonstrated that modeled results are in good agreement with observations. However, large departures, either above or below this line, highlight discrepancies in the realism of the RAMS (original parameterization) - ECMWF relationships.

a) Abha



b) Gizan

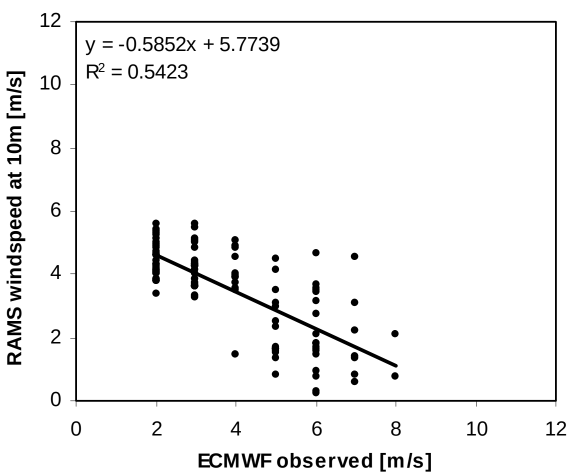


Fig. 7 Correlation of observed data and modeled one for wind speed at 10m for (a) Abha and (b) Gizan from 21 February 2000 to 30 March 2000.

(2) Improved parameterization

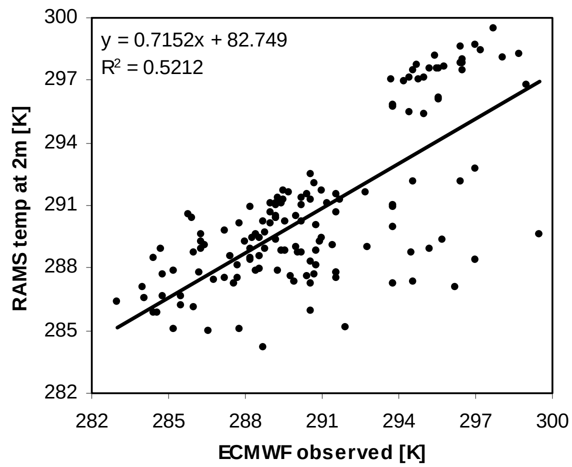
In the control run with original parameterization, the performances of the RAMS model failed in some cases. We improved the parameterization of RAMS model from original one, as follows.

a) Different interpolation scheme for topography: RAMS uses 4 different ways of interpolating topography. In the improved model topography has been interpolated using the ‘conventional mean’-method.

b) A new cloud microphysic is parameterizised: The shape parameter of the gamma distribution is changed to a higher value, which means that the cloud spectrum is much narrower.

c) Nudging model with ECMWF data on all 3 grids: The nudging of the ECMWF input file in the underlying grids fails after 6 hours simulation. To make sure the ECMWF input file is available in the underlying grids the model is nudge with ECMWF data on all 3 grids.

a) Abha



b) Gizan

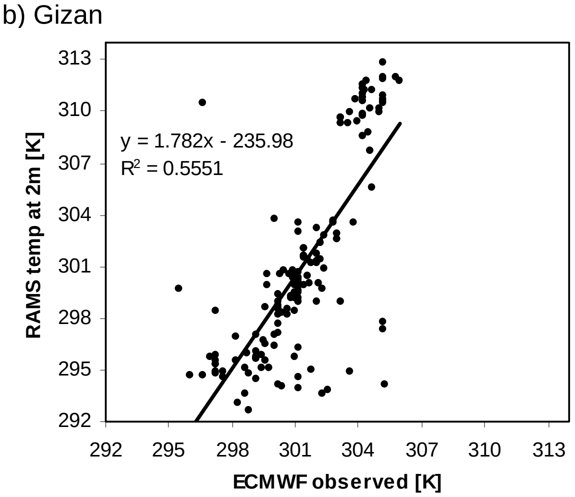


Fig. 7 Correlation of observed data and improved model one for wind speed

As a results of these improvements, the temperature and the wind results shows better agreement with the observations, than original one.

5. Influence of a land use change on rainfall
5.1 Greening conditions

A RAMS simulation is performed by changing land use in the coastal plain from desert to short grass. Greening area was assumed to be 75km width x150km length, as shown in Fig. 8.

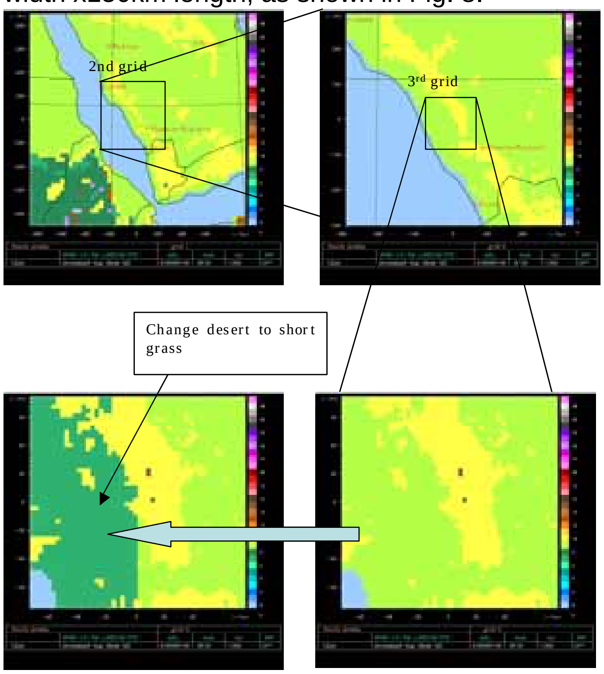


Fig. 8 Nesting grid and change of vegetation category from desert to short grass in coastal desert of 150km(NS) ×75km(EW)

The simulation is carried out for 2000-11-9 until 2000-11-10, when significant rainfall was observed in this area as shown in Fig. 9.

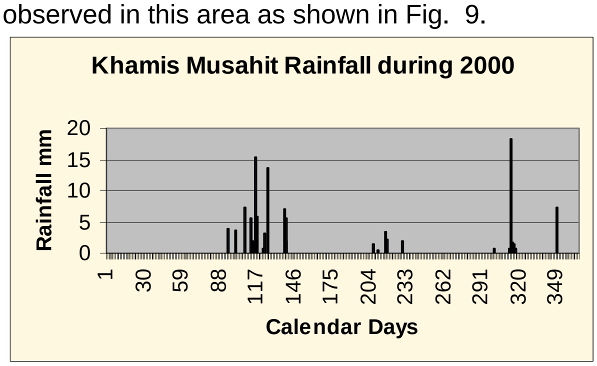


Fig. 9 Daily averaged rainfall variation in Khamis near Abha during 2000

5.2 Simulated results of rainfall

Changing the land use, the cloud mixing ratio and the rainfall intensity are increased by 20%. The water vapor was supplied from the greening area and condensed over the mountain area. These results indicate that there is a possibility of rain enhancement by greening.

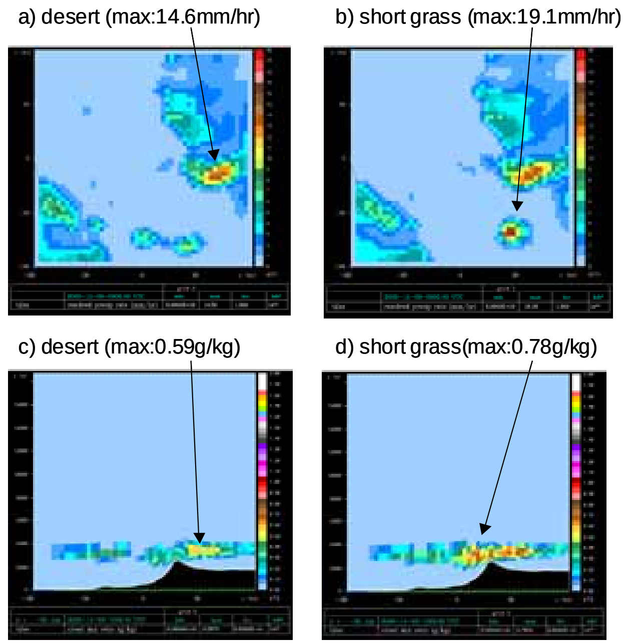


Fig.10 a) and b): Horizontal distribution of rain fall, and c) and d): vertical distribution of cloud mixing ratio

3D view of cloud and rainfall in Fig. 11 shows the relationship between topography and rainfall.

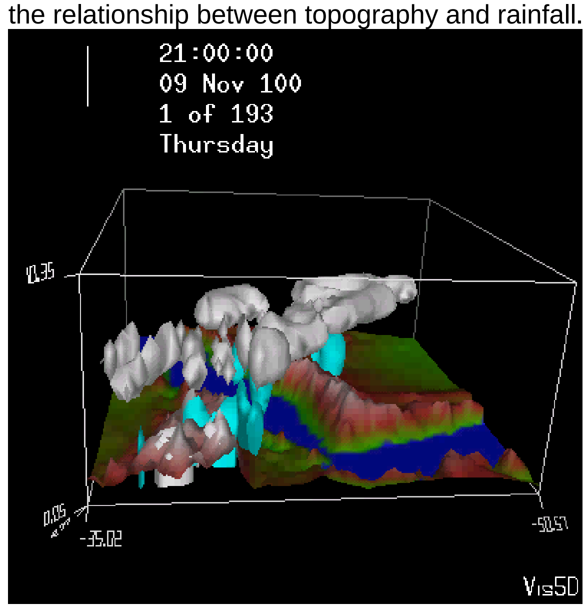


Fig. 11 3D view of simulated results for cloud (white color) and rainfall (blue color)

6. Conclusions and future work

It was found from this preliminary study that
(1) Rainfall pattern of RAMS model was validated with satellite images of INDOEX and TRMM observations.
(2) Temperature and wind results indicate a significant improvement by optimizing the parameter of the RAMS model.

The next target area is the desert between Jeddah and Mecca, Taif, shown Fig. 12. Simulations are now under going by both of MM5 and RAMS models, under the below combinations of vegetation and greening area:

1) Vegetation conditions: change desert in short grass, shrub land and tall tree land.
2) Domain: 150kmx75km, 75kmx37.5km and 37.5kmx18.7km

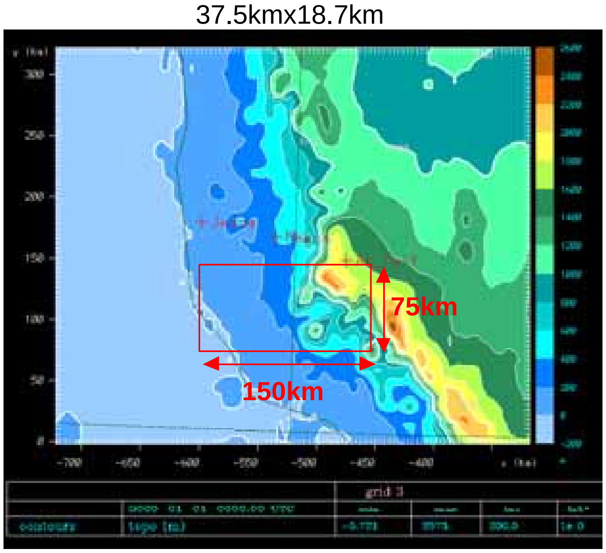


Fig. 11 Next target area of simulation study for the relationship between greening and rainfall

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RAMS model: http://www.atmet.com/html/rams_soft.shtml

Earth Simulator: http://www.es.jamstec.go.jp/