Refinement of Prediction System of Global Water Cycle

Project Representative

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This study conducted the following two simulations to investigate and predict a mesoscale water cycle in Asia- monsoon area, considering the global climate change.

(1) Simulation by mesoscale model of water cycle (West Asia)

Improvement and validation study were conducted for meso and local scale water cycles. Using this improved model, the candidate site for greening in Arabian Peninsula was selected, and effect of rain enhancement by greening was investigated.

(2) Simulation by integrated global circulation model of atmosphere and ocean (East Asia)

We performed a deforestation scenario experiment changing to the cropland from the tropical forest for Southeast Asia by a high resolution CGCM (T213) that includes the SiB land-surface scheme (Sellers et al., 1986). In this paper, we report the effects of a vegetation change on the local seasonal climate of Indochina Peninsula through comparing between the control simulation and the deforestation simulation.

Keywords: RAMS, mesoscale, GCM, vegetation, Asia-monsoon

Scientific Achievements:

1. Numerical simulation of greening effects on precipitation by mesoscale meteorological model

Effects of a large-scale irrigation area (36 × 90 km) was studied in the desert in the southwest coastal region of Saudi Arabia (Figure 1-1).

It is shown in Fig. 1-2 that most of the times lower temperature and higher vapor mixing ratio occur for the "greening" run in comparison to the "control" for a position in the green belt in front of the Asir mountains. The temperature cooling effect of the green belt is especially high on those days where the vapor mixing ratio in the green run is high. The available water is transformed to vapor by evapotranspiration and leads to a higher latent heat flux and with this to a lower sensible heat flux.

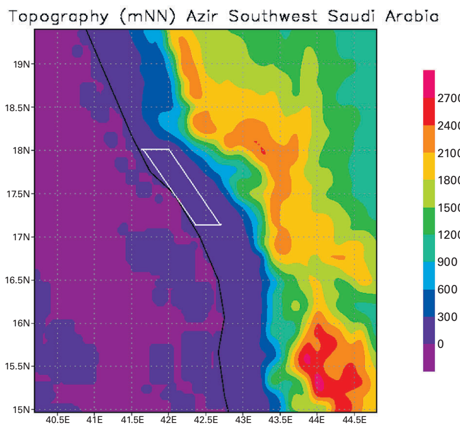

Fig. 1-1 Study area of southwest Saudi Arabia.

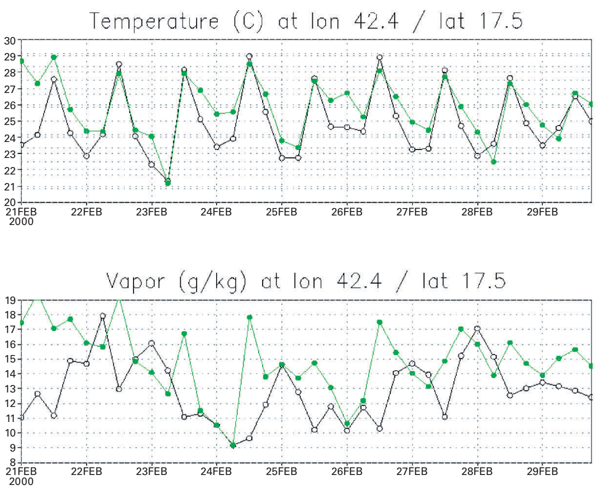

Fig. 1-2 Comparison of temperature and vapor.
For control and greening runs.

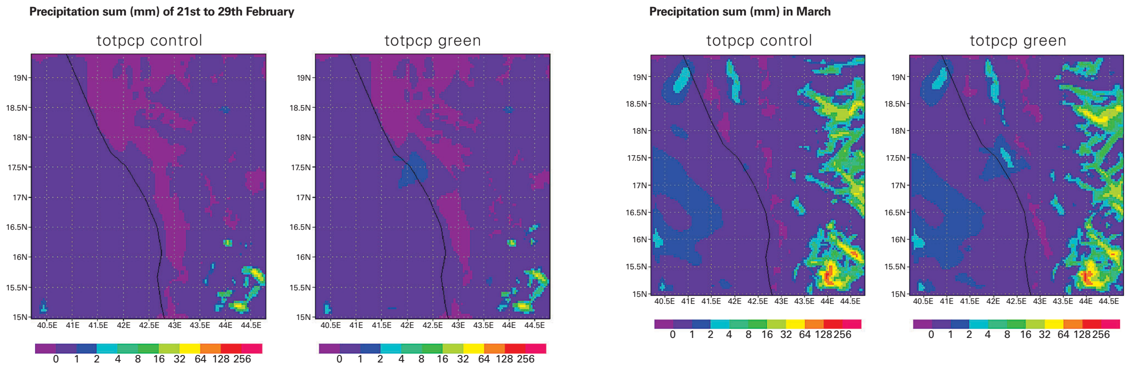

Fig. 1-3 Horizontal distribution of precipitation calculated by RAMS for control and greening runs.

A considerably amount of rainfall is present in the Asir mountain region due to orographic effects. The green belt contributes an increase of precipitation sum to the otherwise dry costal region. Total amount of precipitation increased in each month by the greening effect. It is about 1 mm in February 1-3 mm in March and more than 2 mm up to 5 mm in April.

2. Climate impact of Indochina deforestation on tropical storm activity in the western North Pacific.

2. 1 Introduction

Change of tropical storm (TS) activity in relation to the East Asia summer monsoon and El Niño-Southern oscillation (ENSO) is investigated under the conditions of deforestation changing in vegetation cover from tropical forest to cropland in the Indochina Peninsula (IP) using a high-resolution atmosphere-ocean coupled general circulation model that integrates a simple biosphere model. In the SiB land surface scheme of CGCM, the grids with the "tropical forest" vegetation classes -those falling between 8°N-30°N, 87.5°E-109°E- were replaced with the "land crop" vegetation class. Vegetation changes in land surface models cause to change three surface parameters: albedo associated with the radiation transport, roughness length associated with the radiation transport, and the change rate of photosynthesis and evapotransipiration associated with sensible heat and latent heat transport.

In the present study, we aim to make a clear how the Tropical storm (TS) activity when the IP deforestation happens extremely in change from the tropical forest to the cropland using a high-resolution CGCM. We discuss how EASM and ENSO change owing to the IP deforestation and how the variations of EASM and ENSO influence the TS activity in the western North Pacific.

2.2 Tropical storm activity of deforestation experiment in the western North Pacific

We display the different characteristics of TSs in the western North Pacific for both cases. A model TS is defined using three physical variables: the sea surface pressure, the wind speed at 10 m, and relative vorticity. To investigate TS behavior, we define a model TS as a disturbance meeting the following criteria: is located in the western North Equatorial Pacific, has a minimum pressure less than 1008 hPa, has a wind speed exceeding 17 ms^{-1}, and has a relative vorticity in 5×10^{-4} s^{-1}. Following this model TS definition, the mean annual numbers of TSs for each 30 year are 32.2 for the control run and 32.3 for the deforestation run and they are nearly equal. In the observation for past 30 years, the mean annual number of TSs is 28. Hence, the annual mean number of TSs in the model is larger by 13% than in the observation. The seasonal climate values of TS genesis numbers reach a maximum peak in August and a minimum peak in February. This tendency is similar to the observational result (cf. Fig. 2-1). However, the frequency of model genesis TSs during spring-early summer is more than that of observational genesis TSs.

The genesis number of TSs in summer for El Niño period is more in the deforestation run than in the control run (cf. Fig. 2-1 and Fig. 2-2). The genesis number of TSs in the deforestation run increases in the sea area on the southeast side of the western North Pacific because the SST distributes like in the El Niño. TS genesis frequency difference between the control and deforestation runs is related to the circumstance physical parameters such as SSTs, surface winds, surface pressures, and precipitation. Change of the genesis number of TSs correlates with the westerly wind anomalies between 10°N and 15°N over the western North Pacific. The present deforestation simulation shows the same tendency. The difference in SSTs between the deforestation run and the control run displays the El Niño like pattern and the SST values in the TS genesis area have positive anomalies of 0–0.5°C. As to the sea level pressure, the low pressure circulation appears over the south of Japanese Island. The much amount of precipitation distributes along the TS tracks and occupies the difference with the extent of 10–50 mm/day.

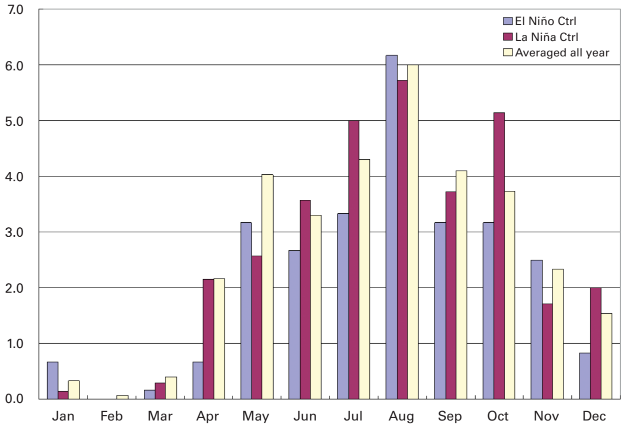

Fig. 2-1 Monthly mean number of model TSs averaged for 30 years for the control run.
Dark bar charts depict in El Niño period, gray bar charts depict in La Niña period, and white bar charts depict in averaged all years.

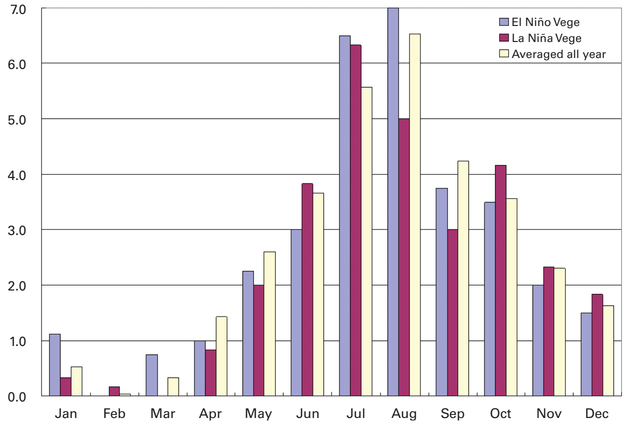

Fig. 2-2 Same as Fig. 1 but for deforestation run.

広域水循環予測システムの高度化

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本研究は、京都大学防災研究所、防災科学技術研究所を中心とした共生PJ課題5グループの水循環研究と地球フロンティアの全球気候モデル研究を連携させることで、全球的な水循環に関するメカニズムとその変動の解明と、全球的気候変動を考慮したアジアモンスーン地域の領域規模水循環、流域規模水循環の解明および予測のため、次のモデル実験を行った。

(1) 域規模水循環モデルによる実験

サウジアラビアの南西海岸部に位置する砂漠において、大規模緑化を行った場合の気象変化を計算した。計算は、現状(control)と緑化後(greening)について、気温、湿度、風速、降雨量などの変化を解析した。砂漠に隣接する内陸の山岳地帯(高度2000～3000m)では、現状でも、地形の影響で年間300mm程度の降雨が観測されている。緑化後は、砂漠地帯でも、月数mm程度の降雨量増加の可能性があることが計算結果から分かった。

計算は、米国コロラド州立大学で開発されたRAMS (Regional Atmospheric Modeling System)を、オランダWageningen大学で降雨モデルを改良し、三菱重工と共同で実施した。砂漠の緑化では、大量の灌漑水が必要であり、現在は、深層地下水（化石水）が利用されているが、この研究では、持続的な水資源として、太陽熱を利用した海水淡水化装置の利用を検討している。既存の領域気象モデルでは、灌漑水の蒸発量を地面境界条件として設定できないので、今回は、灌漑水と等量の降雨量を地面境界条件として設定するように、RAMSを改良した。

この計算結果は、サウジアラビア政府機関（気象環境庁、水電力省など）に報告し、今後の砂漠緑化計画に利用されている。

(2) 大気・海洋大循環統合モデルによる実験

本研究の最大の目的は気候変動に伴う東アジア域の水循環変動を予測することが可能な大気・陸域・海洋水循環統合モデルを開発することである。ENSOや数十年変動のような気候変動を再現性良くシミュレートするためにT213大気海洋結合モデルを使う。この結合モデルは積雲対流スキームとしてKuoスキームから予報型Arakawa-Shubertスキームに変更することによってENSOの再現性および総観スケールの現象としての台風の再現性が非常に改善された

この結合モデルを使って、現状の植生分布のコントロールランとインドシナ半島が森林伐採されたとした植生改変ランをそれぞれ45年間地球シミュレータによってシミュレーションし、16年以降の30年間のそれぞれのケースの季節気候値を比較解析した。モデルシミュレーションではインドシナ半島のすべての樹林を耕作地に改変した（森林伐採）場合、その局地的な地域だけでなく、インド洋から太平洋にかけたグローバルな領域も森林伐採の影響を受けていることが分かった。

キーワード：RAMS，メソスケール，GCM，植生，アジアモンスーン