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学 位 論 文 要 旨

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題目: Monitoring and Simulation of Long-range Mineral Dust from China and Mongolia

中国およびモンゴルからの長距離輸送鉱物ダストのモニタリングとシミュレーション

Dust sources and transport were identified by using coupled methods: satellite remote sensing and trajectory analysis. Identified dust by satellite images was further modeled by importing into atmospheric radiative transfer model, and methodology for retrieving physical and optical properties is presented and discussed. In addition, a dust event was studied by satellite monitoring, in-situ observation, and synoptic analysis. This integrated method revealed the mechanism responsible for dust emission, transport and deposition. Finally, this dust event was modeled by running a regional climate model; the accuracy of the model was tested and necessary improvements were discussed.

Dust sources and transport pathways identification

More than 400 Moderate Resolution Imaging Spectroradiometer (MODIS) images of dust storm events were collected and analyzed, and individual events were tracked back to their origins. Dust tracks were determined from color composite images, brightness temperature difference (BTD) and the NOAA Hybrid Single-Particle Lagrangian Integrated Trajectory model. We identified five dominant regions of dust origin by using time-series MODIS images. Of these regions, sandy lands and stony deserts in northern China and Mongolia were the most productive sources, accounting for about 90% of the long-range dust events originating in the study area. Sandy lands, constituted the dominant source areas (accounting for more than 50% of events) in northern China and Mongolia. The Gobi Desert in Mongolia and western Inner Mongolia was responsible for nearly of 30% dust emission events in the study area. The Taklimakan Desert, which has been supposed the most important dust source, was shown to be a local dust source in most cases. Moreover, dust was mostly emitted from its northeastern edge, where salt pans and dry river beds lie between the desert and large alluvial fans. Because of the topographic constraints of this region, dust from this region usually also affected the neighboring Hexi Corridor.

Retrieval of dust optical depth

The BTD method can be used easily to discriminate dust from clouds and land provided that a suitable threshold value is selected, because clouds usually have positive BTD values and land has BTD values near zero. The relationship between the BTD at bands 31 and 32 and the optical depth of dust can be described by a logarithmic model. The model of this relationship then could be employed to retrieve the optical depth of dust. Model simulations showed that this method could be applied to arid and semiarid regions. A higher surface temperature increases the contrast under dust-laden conditions, making it easier to detect dust provided that the surface albedo is below 0.5. Water vapor in the atmospheric profile weakens the BTD information used to detect and retrieve dust aerosols only when the water concentration is very high. This method, therefore, is still useable in regions that are susceptible to precipitation. A retrieval method of the dust optical depth based on the BTD was developed as a function of solar and satellite geometry. Application and sensitivity analysis showed that this method could be widely used, except under extremes of water vapor and surface albedo.

Synoptic analysis of dust event

Dust outbreaks are associated with topographical characters and surface conditions, but they are also related to synoptic factors, including wind speed, polar vortex intensity, Mongolian cyclone activity, cold fronts, and cutoff low and dry squall development. Dust events from 6–11 April 2001, including 2 episodes with different origins, were identified by using satellite remote sensing. The first episode originated mainly in southern Mongolia and central Inner Mongolia, China, and was caused by the intensive development of a Mongolian cyclone. The second episode originated in the Taklamakan and Badain Jaran Deserts, and especially from the north rim of the Taklamakan Desert. The dust event from these deserts was induced by a surface cold front from the northwest. Synoptic analysis clearly demonstrated the different mechanisms responsible for the two separate episodes. This study depicts a pathway for mineral dust transport from the Taklamakan Desert to the North Pacific Ocean; it is different from other reported pathways, whereby the dust is first moved north and northwestward to 50ºN and then transported to the North Pacific Ocean by the westerly jet stream. The dust that we studied here moved northeastward, escaping the geophysical surroundings through the opening between the mountain ranges.

Numerical simulation of dust emission, transport and deposition

Quantitative estimates of dust emission, transport and deposition are highly desirable but are still not possible, because many issues remain to be resolved in the filed of research. The prediction and quantification of individual dust storms is of great importance as it is not possible otherwise to understand the entire dust cycle in the atmosphere. Numerical simulation of dust emission, transport and deposition was carried out by using a regional climate model (RegCM). This simulation proved that the rims of deserts are important contributors to dust emission in Xinjiang. Although RegCM gave a good simulation over Takalimakan Desert, there are some differences between simulation and observations by both MODIS and TOMS. First, dust aerosols from southern Mongolia and Otintag sandy land were not identified. In addition, northern Xinjiang contributed much to the dust emission, as was not observed by satellites. As a result, RegCM might overestimate dust emitted from Northern Xinjiang, but underestimate those from southern Mongolia and Middle Inner Mongolia, especially Otintag sandy land. Second, the track of the dust aerosols observed by satellites was mainly northeastward, different from the eastward one during 6-7 April and the southeastward on 9-11 April, simulated by RegCM. This dust event was induced mainly by Mongolia cyclones, but the specific features of Mongolian cyclone were not reproduced by RegCM. The discrepancies between simulation and observation may result from the less accuracy of surface characters over the domain. Further accurate parameterization of dust module in RegCM is of urgent necessity for understanding an individual dust event and then the dust cycle in the atmosphere.