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Synoptic scale analyses of the cloud microphysical properties using MODIS 5-kilometers sub-sampling radiance dataset

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1. INTRODUCTION

5-km sub-sampling MODIS radiance dataset (MOD02SSH) were analyzed to retrieve cloud optical thickness (TAU) and effective radius (RE) over the synoptic scale area of the First ISCCP Regional Experiment (FIRE), and Atlantic Stratocumulus Transition Experiment (ASTEX) region. Although MOD02SSH dataset is a reduced-volume dataset that has data size of 1/25 from the original, it retains Instantaneous Field of View (IFOV) of every pixels and “texture” of viewing. Thus, the results contribute to the process studies, such as the cloud droplet growth model that needs many retrieval samples with fine spatial and temporal resolution. TAU versus RE scatter diagrams at each area will have a information of cloud growth at the certain area, thus, comparison between satellite-retrieved results and model-simulated results of TAU-RE scatter diagram will yield better understandings of cloud system. In this study, we found interesting features in MODIS-retrieved TAU-RE diagrams that will be explained as the cloud properties under the pristine and turbid environments, by the spectral microphysics cloud model.

2. ADVANTAGES IN MODIS 5-KM SUB-SUMPLING SUBSETS

Since the cloud retrieval requires relatively high-cost computing resources, the most analyses for global scales used the drastically reduced-size subsets of satellite-borne radiance. For example, Han et al. (1994) retrieved cloud properties for global scale using near-nadir looking AVHRR data (satellite zenith angle < 26 degrees). Kawamoto et al. (2000) used segment AVHRR data that are map-projected radiances at every 0.5 degrees in latitude and longitude segment boxes for a whole globe (each segments has 10x10=100 pixels of radiance data). In fact, these subsets degrade the spatial fineness of analyses (and textures were disturbed), whereas reduce the computer resource requirements in both CPU powers and data storages. However, the studies of cloud droplet growth process need finer results than these subsets. Utilizing the sub-sampling radiance dataset is one of suitable solutions for the problem. For example, AVHRR GAC (Global Area Coverage) and MODIS MOD02SSH dataset reduced the dataset size by 5-km sub-sampling, and GLI L2A_OA dataset by 4-km sub-sampling. It is notable that they are retaining the IFOV of each pixel and “texture” of images, but simply reduced data size by 1/25 and 1/16, respectively.

3. CLOUD RETRIEVAL ALGORITHM AND SYSTEM

We used the retrieval algorithm, the Comprehensive Analysis Program for Cloud Optical Measurement (CAPCOM), for cloud microphysical properties developed by Nakajima and Nakajima (1995) with a water vapor correction scheme of Kawamoto et al. (2000). Briefly, it uses the visible channel (VIS) and near-infrared channel (NIR) to retrieve TAU and RE, respectively. Since the VIS (NIR) is sensitive to RE (TAU) too, the retrieval have to be done with two-unknown (TAU and RE) and two-known (VIS and NIR). When one uses 3.7-μm for NIR channel, thermal radiation that is unexpectedly included in the measured radiance should be corrected with helps of

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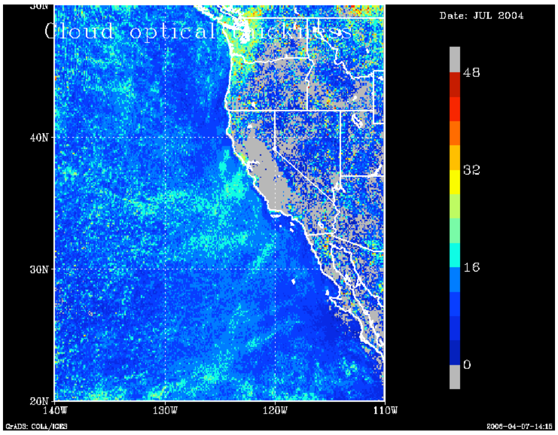

Fig. 1 Cloud Optical Thickness (FIRE, July 2004)

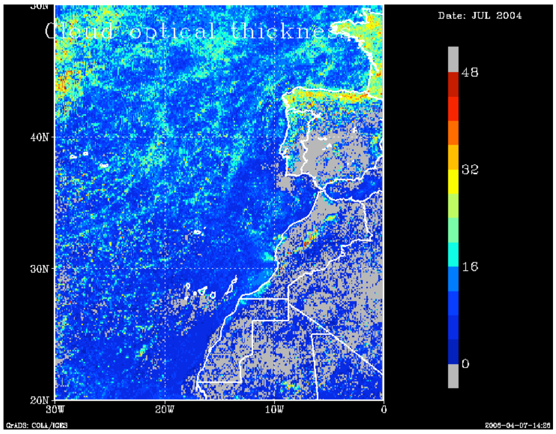

Fig. 3 Cloud Optical Thickness (ASTEX, July 2004)

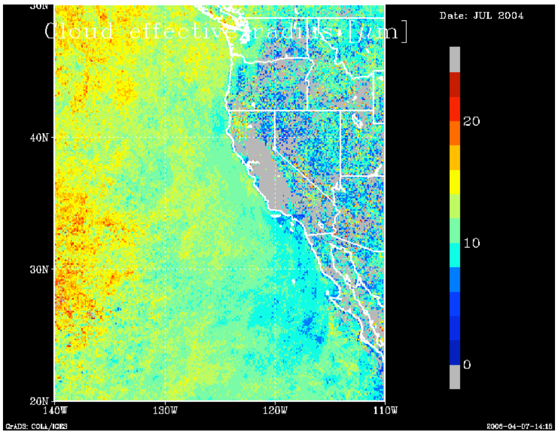

Fig. 2 Effective Particle Radius (FIRE, July 2004)

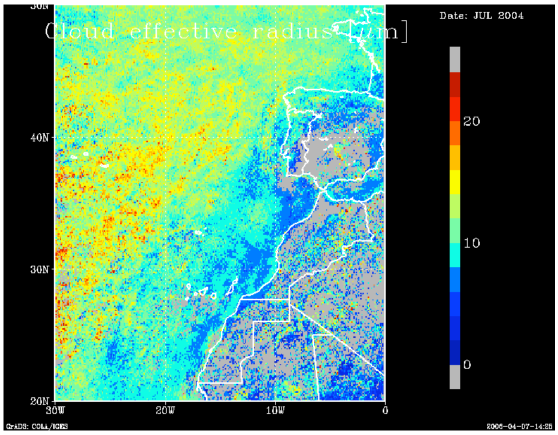

Fig. 4 Effective Particle Radius (ASTEX, July 2004)

11-μm thermal channel. The CAPCOM (previously, it was called "GTR") was developed to ADEOS-II Global Imager (GLI) project as a standard data analysis algorithm. The great progress of the computer technology in this decade enabled us to retrieve cloud microphysical properties faster than before. In facts, about six-hours processing using Intel Xeon (3.2GHz, 2Gbyte Memory) analyzed 1-month MOD02SSH data for the synoptic scale of the FIRE region (110W-140W, 20N-50N) in this research. Thus, we are coming to the new *era* of cloud retrievals that used finer resolution radiance dataset for synoptic scales.

4, TAU-RE scatter plot diagrams over FIRE and ASTEX region in July 2004

One of the advantages in the analysis we proposed is the higher spatial and temporal resolution than previous researches by near-nadir looking and/or segment datasets. Figure 1 and 2 illustrated the one-month mean of retrieved TAU and RE, respectively. (In fact they are "averaged" value, but we analyzed all MOD02SSH viewing images.) Only warm water clouds that have cloud top temperatures (TC) larger than 265K were selected. In general, the RE were larger in oceanic area than coastal zone. This tendency is consistent to the results by Han et al. (1994) and Kawamoto et al. (2001). The typical TAU, off the coast of California, was less than 12. It is interesting that a cloud band where the optical thickness is respectively larger than surrounded area exists from San Francisco to the west direction. TAU was about 20 along this cloud band. Figure 3 and 4 are same as Fig. 1 and 2 but off the west coast of Europe. The typical TAU was around 10. RE were ~15μm in oceanic area and ~10μm along the coastal zone. The highlight of this paper is shown in Figure 5 and 6. These figures showed

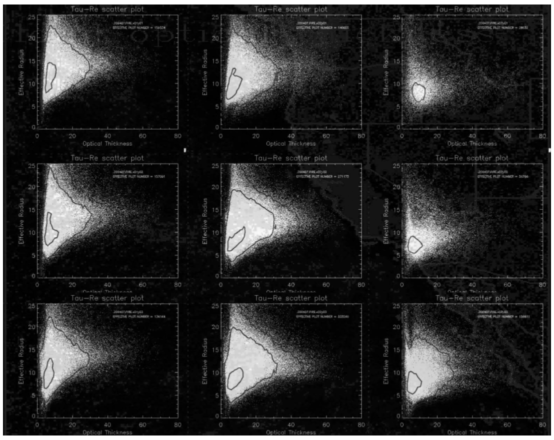

Fig. 5 The scatter diagram of cloud optical thickness (TAU) versus Effective particle radius (RE) (FIRE, July 2004)

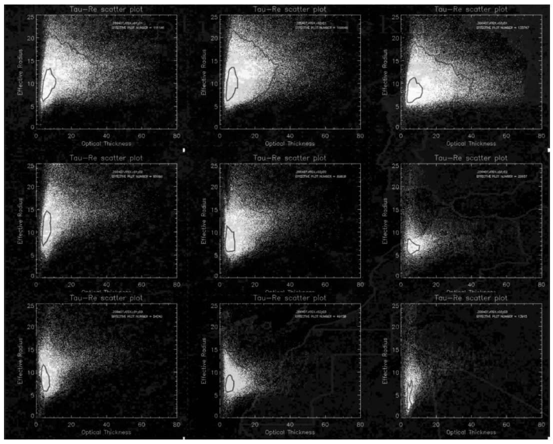

Fig. 6 The scatter diagram of cloud optical thickness (TAU) versus Effective particle radius (RE) (ASTEX, July 2004)

TAU-RE scatter diagrams at every 3 x 3 region of the FIRE (Fig. 5) and ASTEX (Fig. 6). Each region corresponds to the 10 x 10 degrees latitude and longitude square. The number of plots is larger in oceanic area than continental and coastal zone. This depends on the contrast of the cloud occurrence between oceanic and continental area. Mode of the RE is, larger in oceanic area, moderate in coastal zone, and relatively smaller on the continent. As seen in Fig.5 and 6, the typical shape of the scatter plots is isosceles triangle, but symmetries were disturbed in some cases. Probability density function in each panel showed structure of the scatter plots in detail. For example, the left and the middle panels of the second line in Fig. 5 have similar shape of triangle, but the probability densities suggested different cloud systems they have. The most right panel of the third line in Fig.5 showed that the two or three kinds of different cloud systems are included. They are Comparing Fig.5 and Fig.6。

These differences are explained as results of Cloud Condensation Nuclei (CCN) numbers and stability of atmosphere. Figure 7 illustrated

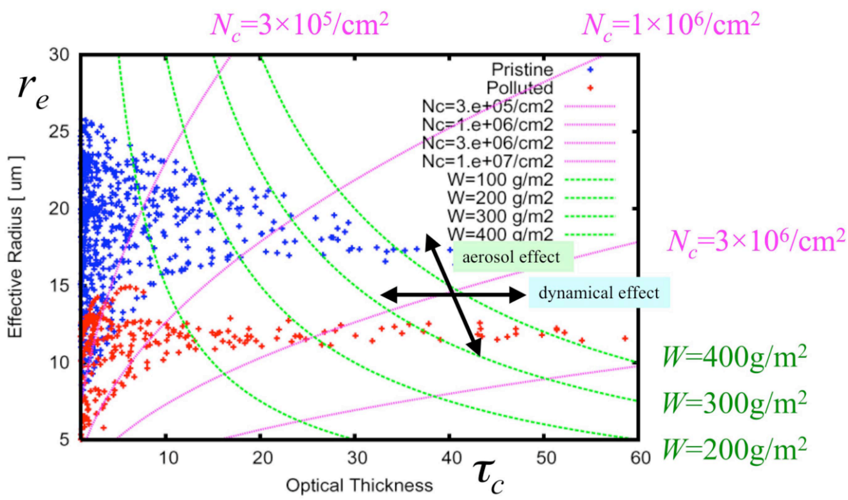

Fig. 7 Model-simulated scatter diagram of cloud optical thickness versus effective particle radius obtained by a non-hydrostatic spectral microphysics cloud model. (This model will be appeared in J2.8 in AMS 12th conference on cloud physics.)

model-simulated scatter diagram of cloud optical thickness versus effective radius obtained by a non-hydrostatic spectral microphysics cloud model (Suzuki et al. 2006, J2.8 in AMS 12th conference on cloud physics). The blue dots are cloud properties under the pristine air condition, whereas red dots are under the polluted air condition. The pink and green curves illustrated the iso-CCN curves (Nc= 3×10^5, 1×10^6, 3×10^6, 1×10^7/cm2) and iso-cloud liquid water path curves (W=400, 300, 200, 100g/m2), respectively. In this figure, we found a large negative correlation pattern with small fragment of positive correlation in pristine condition, whereas found a positive correlation patterns in polluted condition with suppressed effective particle radius. Comparing Fig 5 or Fig.6 with Fig. 7 suggested the difference of cloud growth process. For example, the most panels in Fig. 5 are similar to the scatter plots of pristine condition than to the polluted condition. On the other hand, the most right panel of the 1st line in Fig. 6 suggested the mixture of the pristine and polluted condition in the cloud growing since a negative correlation pattern is predominant in this panel but, at the same time, the effective particle radii seemed to be suppressed around RE=5 to 10μm.

5, Conclusion

Synoptic scale of the cloud microphysical retrievals have been performed by using 5-km sub-sampling MODIS radiance dataset, for the purpose of contributing the cloud forming process studies. One of the advantages in the analysis we proposed is the higher spatial and temporal resolution than previous researches by using near-nadir looking and/or segment datasets. From the MODIS analyses in July 2004 over the FIRE region off the coast of California, we found the TAU-RE scatter diagrams that will be clouds formed in pristine air condition suggested by non-hydrostatic spectral microphysics cloud model. On the other hand, TAU-RE scatter diagram that will be cloud formed in the polluted air condition appeared over the land area of ASTEX region. These are very reasonable results and consistent to our knowledge such as aerosol indirect effects in cloud growing.

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