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DIURNAL CYCLE OF CLOUD SYSTEMS OVER NORTH AMERICA AS OBSERVED BY SATELLITE INFRARED DATA

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1. INTRODUCTION

Despite its importance, the diurnal cycle of cloud systems over the globe has not been examined thoroughly, due primarily to the lack of a cloudiness data set with appropriate temporal and spatial resolution. Recently, a new system has been established at the NOAA Climate Prediction Center (CPC) to produce gridded fields of cloud top / surface temperature on a 4km x 4km resolution over the globe [60°S-60°N] in a half-hourly interval [Janowiak et al. 2001]. The global fields of surface / cloud top temperature are defined by merging and inter-calibrating infrared (IR) observations from five geostationary satellites and are available on a quasi real-time basis beginning from February 2000.

In this work, we examine the diurnal cycle of cloud systems associated with the North American Monsoon System [NAMS] for summer 2003 using this full resolution IR data set.

2. THE IR DATA

To investigate the diurnal cycle of clouds associated with the NAMS, the half-hourly full resolution IR data over Mexico, Southwest United States and their adjacent oceanic areas [120°W-90°W; 22°N-32°N] are extracted from the global fields. Three-hourly values of fractional coverage of clouds colder than 215°K, 235°K and 255°K are calculated on a 0.25°lat/lon grid over the domain for a 6-month period from May 1 to October 31, 2003. For convenience purposes, the fractional coverage of clouds with cloud top temperatures of colder than 215°K, 215°K-235°K, and 235°K-255°K are used to define the cloudiness for high, middle and low clouds, respectively.

3. DIURNAL CYCLE

As a first step, we examined the spatial distribution of mean cloudiness over the 6-month period from May to October of 2003 (figure 1).

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Clouds associated with the North American Monsoon System [NAMS] appear as wide and smooth bands over both the west and east coasts of Mexico along the mountain ranges. Cloudiness is more frequent over the west coast than the east coast.

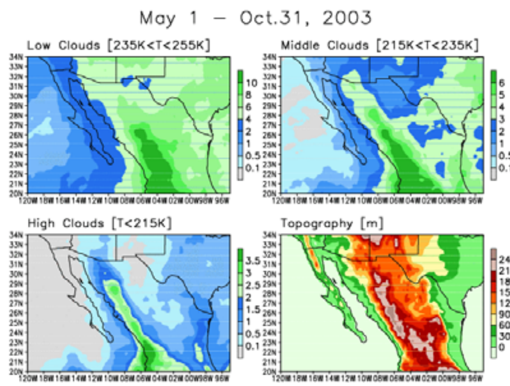

Fig.1: Distribution of the 6-month mean cloudiness (%) for low (top left), middle (top right), and high (bottom left) clouds, together with elevation (m) over the target domain.

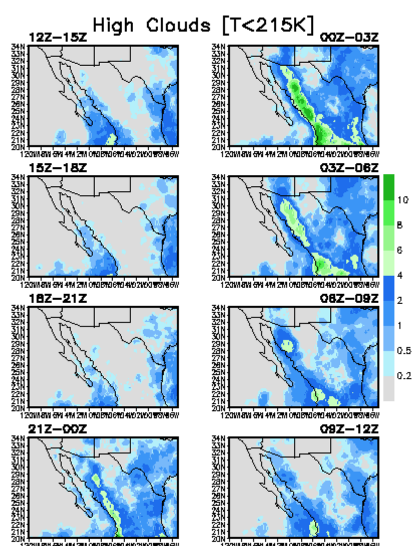

Fig. 2: Distribution of 3-hourly cloudiness (%) for high clouds averaged over the 6-month period from May to October, 2003.

A strong diurnal cycle of cloudiness is observed over the 6-month period. The high (cold) clouds, which are an indication of convective activity and precipitation, have a minimum in coverage in the morning [12Z-15Z], develop their extension in the afternoon and reach the maximum in late afternoon [00Z-03Z, Fig.2]. The frequency of the low clouds [Fig. 3] exhibits a diurnal cycle similar to that of the high clouds but with the maximum delayed for ~3 hours.

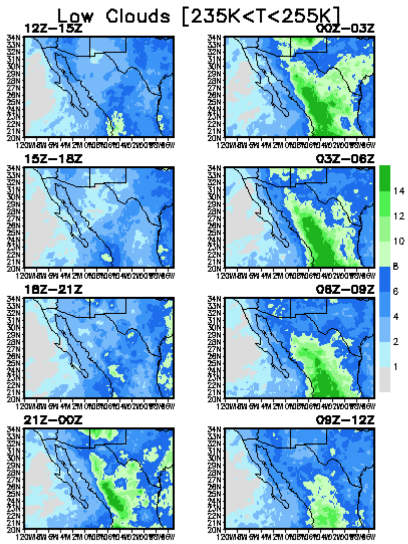

Fig. 3: Same as in fig.2, except for low clouds.

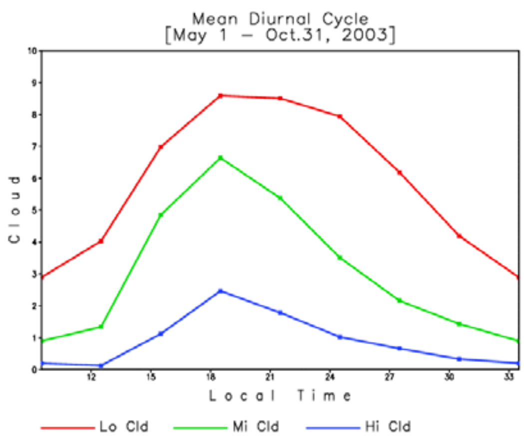

Fig. 4: Diurnal cycle of cloudiness for high (blue), middle (green) and low clouds (red) averaged over a spatial domain from 22°N-32°N, 5° west and east to the crests of the Sierra Madre Occidental mountain range for a 6-month period from May 1 to October 31, 2003.

To further quantify the diurnal cycle of clouds associated with the NAMS, mean values of cloudiness are calculated over a spatial domain from 22°N-32°N and 5° west and east to the crests of the Sierra Madre Occidental mountain range. On average, clouds starts at ~09LST, reach maximum at ~18LST and then diminish during evening time. A flat tail is observed in the amount of low clouds after they reach the maximum, a reflection of the existence of canopy of cirrus, which has similar TBB as the low clouds, after the peak of convection.

A brief examination of the time series of the mean cloudiness over the spatial domain (Fig. 5) shows that the phase of the diurnal cycle is relatively stable throughout the period, while its magnitude presents changes of synoptic and intraseasonal time scales, indicating that the diurnal cycle is modulated by the large-scale circulation and moisture fields.

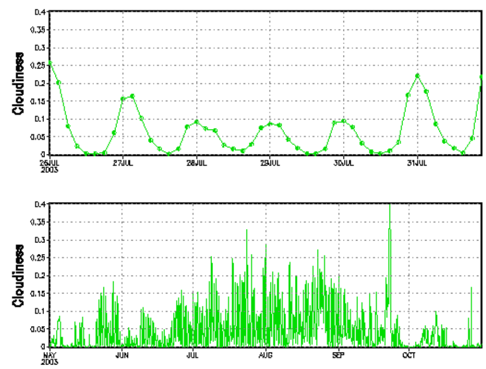

Fig. 5: Time series of middle cloud amount averaged over a spatial domain from 22°N-32°N, 5° west and east to the crests of the Sierra Madre Occidental mountain range for a 6-month period from May 1 to October 31, 2003. The top panel shows the results for a subperiod of 6 days, while the bottom panel presents time series for the entire period.

4. OROGRAPHIC EFFECTS

Topography plays an important role in driving the regional circulation and thereby the evolution of cloud systems. To examine the relationship between orography and cloudiness, composite maps of the east-west section of mean cloudiness are constructed for each of the 3-hourly box and relative to the position of mountain crest [Fig.6]. Cloud systems start from higher elevation in the morning, move toward the coast as they reach the maximum in late afternoon.

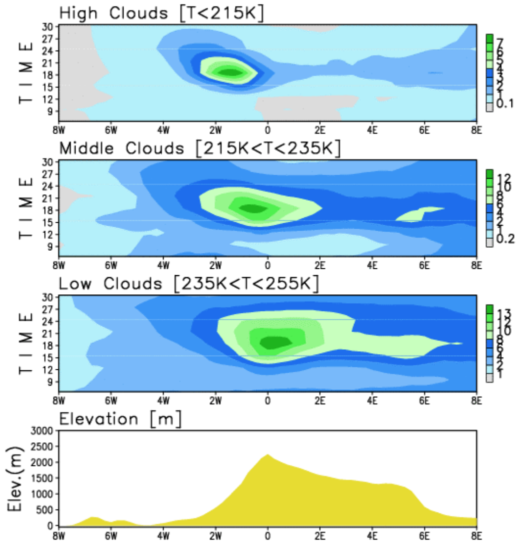

Fig. 6: *East-west section of 3-hourly mean cloudiness averaged from 22°N to 32°N relative to the crests of the Sierra Madre Occidental mountain range, together with the mean elevation (bottom).*

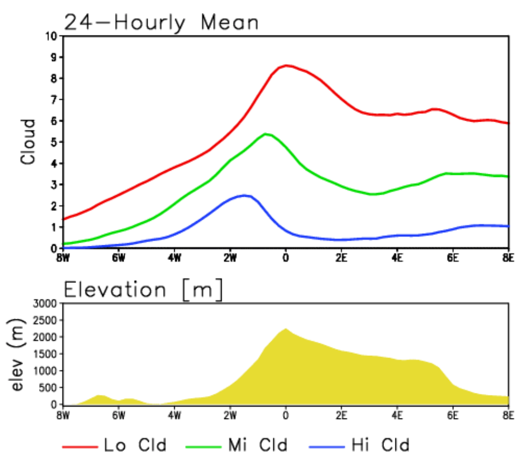

Fig. 7: *East-west section of 24-hourly mean cloudiness averaged from 22°N to 32°N relative to the crests of the Sierra Madre Occidental mountain range, together with the mean elevation (bottom).*

An east-west section of the 24-hourly mean cloudiness [Fig. 7], meanwhile, shows that position of maximum cloudiness for higher clouds is west to that for warmer clouds, with the center of deep convection located ~100km west to the mountain crest.

5. SUMMARY

A comprehensive diagnostic study has been performed to describe the temporal-spatial structure of the mean state and diurnal cycle of the NAMS cloud and precipitation systems for a 6-month period from May 1 – October 31, 2003. Our results showed the following:

1) Variations of cloudiness associated with the North American Monsoon System (NAMS) are dominated by the diurnal cycle;

2) Clouds start from higher elevation in the morning, move toward the coast as they reach the maximum in late afternoon;

3) The phase of the diurnal cycle is relatively stable, while the magnitude presents changes of synoptic and intraseasonal time scales; and

4) Maximum of deep convection appear ~100km west to the mountain crests.

REFERENCES

Janowiak, J.E., R.J. Joyce, and Y. Yarosh, 2001: A real-time global half-hourly pixel-resolution IR dataset and its applications. *Bull. Amer. Meteor. Soc.*, **82**, 205-217.