Assessment of Clouds Simulated by NOAA GFS and NAM Models Using Satellite Products

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1.INTRODUCTION

Clouds are recognized as main sources of uncertainty in predicting global weather and in estimating climate model capabilities. Cloud microphysical and optical properties on a global scale vary widely from model to model. This study aims to evaluate cloud properties generated by NCEP's Global Forecast System (GFS) and North American Mesoscale (NAM) models through use of satellite retrievals of the same cloud properties, from CloudSat, CALIPSO, and Moderate Resolution Imaging Spectroradiometer (MODIS).

2. METHODOLOGY

❖ MODIS Level 2B cloud product MOD06 (ver. Collection 5) sampled every fourth day of July 2007 and 2008 (i.e., day 2, 6, 10, 14, 18, 22, 26, and 30).
❖ Cloud optical depth from the CloudSat Level 2B TAU product and cloud fraction from the CALIPSO product, these data were smoothed onto a 4º X 8º latitude-longitude grid for mapping, plotting, and global analyses.
❖ GFS Grid 003 data with a spatial resolution of 1º X 1º latitude-longitude. Model output at three-hourly interval forecast times (i.e., 03, 06, 09, 12, 15, 18, 21, 24 Z) from control time 00 Z are selected for July 2007.
❖ NAM Grid 218 data with resolution of 12 km X 12 km for July 2008. High, mid, and low cloud cover were selected.

2.1. Cloud Fraction

A. Satellite Data

Each 1º X 1º grid box contains a monthly average of cloud fraction output from the Chang and Li (2005) algorithm using MODIS data based on a daily average. Cloud fractions are calculated as the numbers of pixels in a grid box corresponding to a particular cloud type (high, middle, or low) divided by the total number of pixels (including clear-sky pixels) falling in the grid box.

B. Model Data

The GFS cloud fraction product has four different cloud categories: high, middle, low, and boundary layer cloud. The low cloud fraction is calculated by applying the maximum overlap assumption between low level cloud fraction and boundary layer cloud fraction

The NAM cloud fraction variables were extracted from original NAM output files. All results' of models were interpolated with satellite observation UTC time.

2.2. Cloud Optical Depth (COD) for GFS

The cloud water mixing ratio variable from the GFS model is used and includes both liquid and ice contents which are differentiated using the mean cloud layer temperature (ice if Tc < -10ºC). For ice clouds, re is a linear function of temperature:

$$r_{ei} = 1.5 * Tc – 314.74 ,$$

where Tc is in units of K. There is no retrieval when Tc is below 210.16 K. And the COD for ice clouds, τi, is calculated as:

$$\tau_i = IWP(a3 + (a4 / r_{ei})).$$

2.3. Ice Water Path (IWP) for GFS

Due to the lack of detailed information concerning the vertical distribution of the cloud ice water path, the sum of each layer IWP is used to determine the cloud IWP for each cloud category.

$$IWP = q * p * \Delta z,$$

where q is the cloud water mixing ratio, p is the density, Δz is the geopotential height thickness, and q is the average of values at the top and bottom of the cloud layer.

3. RESULTS - GFS

3.1. Cloud Fraction

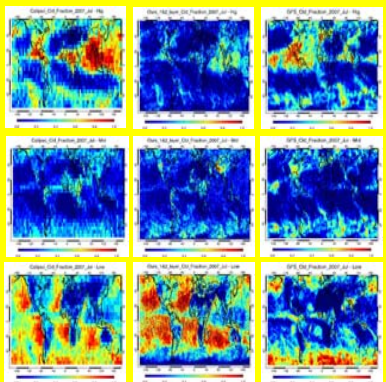

Figure 1. Monthly mean cloud fraction from CALIPSO, the C-L algorithm, and the GFS model for July 2007. Upper, middle, and bottom panels represent high, middle, and low cloud fractions, respectively.

3.2. Cloud Optical Depth

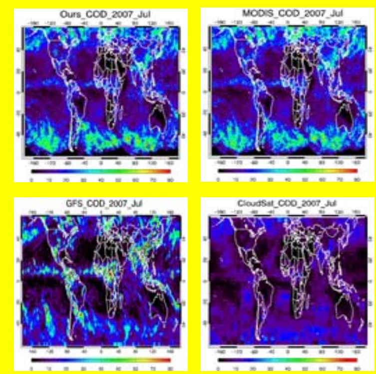

Figure 2. Total cloud optical depth from the C-L algorithm (upper left panel), MODIS (upper right panel), the GFS model (lower left panel), and CloudSat (lower right panel) for July 2007.

3.3. Ice Water Path

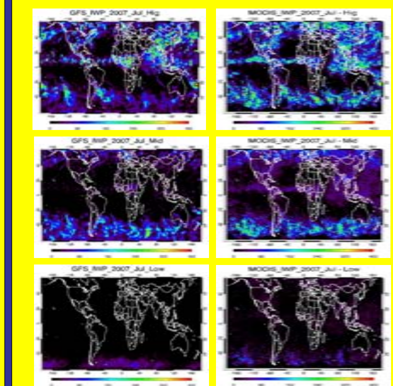

Figure 3. Ice Water Path (IWP) from MODIS and the GFS model for July 2007. Upper, middle, and bottom panels represent IWP for high, middle, and low clouds, respectively.

3. RESULTS - NAM

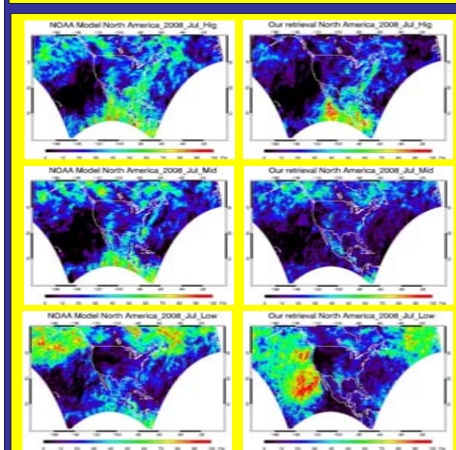

Figure 4. Monthly Mean cloud fraction from NAM and C-L algorithm for July, 2008. Upper, middle, and bottom panels represent high, middle, and low cloud fractions, respectively.

4. SUMMARY

1.Generally, the GFS model produces reasonable total cloud patterns on the global scale, and NAM does an even better job in North America region.

2. But the GFS generates more high-level clouds and less low-level clouds than does the C-L algorithm during July 2007..In particular, the GFS model tends to miss low, thin stratus cloud off the American west coast and thick, large-scale clouds associated with the mid-Atlantic storm track region.

3. The maritime high-latitude storm track regions in the Southern Hemisphere are evident from the results of the C-L and MODIS algorithms, but GFS-modeled CODs in the Southern Hemisphere are much less than those from the C-L and MODIS retrievals. Also, CODs over South America and parts of Africa near the equator are overestimated.

4. For high cloud, GFS-modeled IWP is smaller than MODIS retrievals east and west of the North American continent, over Europe, and over the high-latitude region (40 ºS ~) in the Southern Hemisphere during summer. The spatial distributions of middle and low cloud IWP from model and satellite are generally comparable although GFS-modeled middle cloud IWP is missing over the high-latitudes of the both Northern and Southern Hemisphere.

5. The NAM also shows large differences in low clouds fraction at mid latitudes specially, the NAM model did not capture stratus clouds in generating western America and Atlantic ocean.