HOW ATMOSPHERIC INSTABILITY INFLUENCES MODELS RESULTS OF SATELLITE OBSERVED UPPER TROPOSPHERIC WATER VAPOR PROPERTIES

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1. ABSTRACT

Proper depiction of the water vapor distribution in the upper troposphere and its radiative properties is critical for the accuracy of climate and atmospheric circulation model predictions. In this work, differences between satellite observations (from Terra-MODIS) and simulations from atmospheric models outputs are examined. The models are the National Center for Environmental Protection/Department Of Energy (NCEP-DOE) reanalysis-2 data and the Nonhydrostatic ICosahedral Atmospheric Model (NICAM). Outputs of these models (atmospheric temperature and humidity profiles) are used to simulate the upper tropospheric brightness temperature and relative humidity (quantities evaluated in the study) at clear sky and low cloud areas. The study shows the contribution of atmospheric instability due to the lower troposphere clear sky, heat movements' distribution and cloud convection in the increase of discrepancies between modeling and observation results. Differences between model and observation data tend to increase with the proportion of unstable pixels among the clear sky areas. Cloud movements' distribution examined through the cloud effective emissivity show that discrepancies are smaller in full clouds compared to broken clouds. Cloud convection seems to affect mostly the NICAM model results, as a positive correlation can be seen between the error increase and the amount of convective clouds.

2. DATA PROCESSING AND METHODOLOGY

The horizontal spatial resolution considered for the simulations conducted in this study is 0.5×0.5^{o}. The study sites selected are from the Atlantic and Pacific oceans. Atmospheric phenomena (mainly air mass movements) in these areas are examined based on the water vapor absorption channel (6.7 µm) and the IR window channel (11 µm) observations of Terra/MODIS. To understand the differences between model results and observation data, interpretations are conducted in terms of atmospheric instability due to lower troposphere clear sky areas, heat movements' distribution and cloud convection. Lower tropospheric instability characteristics are examined through a commonly used stability indicator, the atmospheric K index. The K index (KI) is a measure of the thunderstorm potential as a function of vertical temperature lapse rate at 850hPa temperature and 500hPa temperature, low level moisture content at 850hPa dewpoint, and the depth of the moist layer at 700hPa dewpoint [1]:

$$KI = \left(T_{850hPa} - T_{500hPa}\right) + T_{d850hPa} - \left(T_{700hPa} - T_{d700hPa}\right)$$

The cloud convection and movements' distribution impacts are respectively examined through a cloud classification scheme highlighting convective clouds, and the cloud effective emissivity.

3. RESULTS AND INTERPRETATION

The study shows that the models examined depict generally well the upper tropospheric water vapor properties. The brightness temperature simulations performed with NCEP/DOE outputs, though constantly overestimated, show superior results to those of NICAM. The examination of the K index shows that the brightness temperature discrepancies between the observations and the models increase with the proportion of the lower troposphere clear sky unstable pixels. Analysis of cloud convection shows that when the proportion of convective cloud systems is high, the errors increase, mainly between the NICAM model and the observations. The drive of moisture due to these clouds enhances the instability of the upper troposphere. This effect tends to be underestimated by the NICAM model as the brightness temperatures obtained in these areas are generally higher. Away from convective cloud zones, models and observations show fewer differences. Good correlations (correlation coefficient above 0.7 for the brightness temperature and 0.6 for the relative humidity) and fewer errors are obtained from scenes with lower amounts of convective clouds. The cloud movement distribution examined through the cloud effective emissivity shows that both models discrepancies with the observations tend to increase with the increase of the amount of clouds having low effective emissivity values. These areas are broken clouds. A better agreement is obtained at high emissivity areas i.e. continuous clouds. Improvements of the models results for better reliability are specifically necessary for the cloud resolving parameters (variation of the cloud fraction coverage).

REFERENCES

[1] George, J.J. 1960.Weather forecasting for Aeronautics, Academic Press, New York, 409-415.