Monsoon Disturbances Over Southeast and East Asia and the Adjacent Seas

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LONG TERM GOALS

To study weather disturbances over the Southeast and East Asian monsoon region and its adjacent seas (e.g., tropical western Pacific, Indian Ocean, South China Sea, Yellow Sea, etc.) using Navy research and operational analysis and forecast models. The primary goal is to advance the understanding of the weather-producing systems in the region, in order to improve forecast capabilities.

OBJECTIVES

The objectives are: (1) to study the structure and the dynamic and thermodynamic properties of the disturbances in the vicinity of the Southeast and East Asian monsoon region that stretches from Indian Ocean to the tropical western Pacific, including the South China Sea and Yellow Sea, which are of particular interest to naval operations; and (2) to study the ability and sensitivity of Navy operational numerical models in analyzing and predicting these disturbances. The current Navy operational model, COAMPS, has not been tested systematically in the tropical, monsoon environment. The importance of cumulus convection, the tropical dynamics, and the topographic effects in East and Southeast Asia and the surrounding seas provide a quite different challenge for the simulation and forecasting capability of COAMPS as compared to other parts of the world. Therefore, an important objective is to study the characteristics of the model's performance and sensitivity in the East Asian monsoon region, in order to improve the model forecast skill and to find the optimal application methodology for Navy operations.

APPROACH

Observational studies/Data analysis: Use archived gridded data from global NWP outputs and satellite data to determine the structure of mesoscale and synoptic disturbances in various local regions for the different seasons. Use composite and principal component approaches to perform statistical analysis of the data.

Dynamic modeling: Use dynamic models to study the interaction of western tropical Pacific monsoon circulation and synoptic tropical disturbances.

Numerical modeling: Perform sensitivity and simulation studies of the observed monsoon disturbances with Navy's regional research and operational models. Cold start with NOGAPS fields and continued integration using update cycles. Carry out sensitivity studies with respect to physical

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14. ABSTRACT
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parameterizations, grid sizes, and data impacts. Verify model forecasts and analyze model results with results of observational study using diagnostic tools.

WORK COMPLETED

1. Conducted numerical experiments to identify major inadequacies of COAMPS simulation of the pre-monsoon onset case of 13-15 May 1998 during the South China Sea Monsoon Experiment (SCSMEX). The first inadequacy is the unrealistic overestimation of the precipitation for a tropical system south of India. The second is the development of fictitious rainfall belts in southeastern tropical Indian Ocean. The third is an excessively large magnitude of surface latent heat fluxes over elevated terrain during daytime, especially over the Tibetan Plateau.

2. Conducted barotropic experiments to study the process of scale contraction and energy dispersion in the development of tropical synoptic disturbances in the western Pacific summer monsoon region.

RESULTS

1. COAMPS errors in the monsoonal tropical oceans

The first major error is the overestimate of rainfall in Indian Ocean tropical system. There are two options of cumulus parameterization schemes in COAMPS: the Kain-Fritsch scheme and the Kuo scheme. In several experiments the Kuo scheme led to rapid false degeneration of most tropical systems, so the Kain-Fritsch scheme was chosen. (A coding error in the K-F scheme that artificially increases the precipitation was discovered in the course of the experiment and was corrected.)

The East China subtropical front and Indian Ocean tropical convection are considered two of the most important systems that affect the onset of the South China Sea summer monsoon (Lau et al 2000). The locations of these two system were reasonably well forecasted (COAMPS forecast precipitation is shown in Fig.1- second column, observed precipitation obtained from Global Precipitation Climatology Project or GPCP is shown in Fig.1 – first column). However, the forecast precipitation of the tropical system (south of India) was unrealistically excessive (>275 mm for the maximum 0-24 hr accumulated precipitation). This problem may be associated with cumulus parameterization or the sea surface temperature data. The Kain-Fritsch scheme was designed for the mid-latitude convective system. Preliminary results suggests two possible sources of problems. The first is the relationship between the precipitation efficiency and the wind shear used in Kain-Fritsch scheme, which now is an empirical function obtained from mid-latitude cases. The other is the lifetime of the convective cloud, which is reciprocal to the environmental wind speed. Since the wind speed over tropical area is relatively small. the lifetime of the convective cloud may be overestimated. Ways to resolve these issues are being studied.

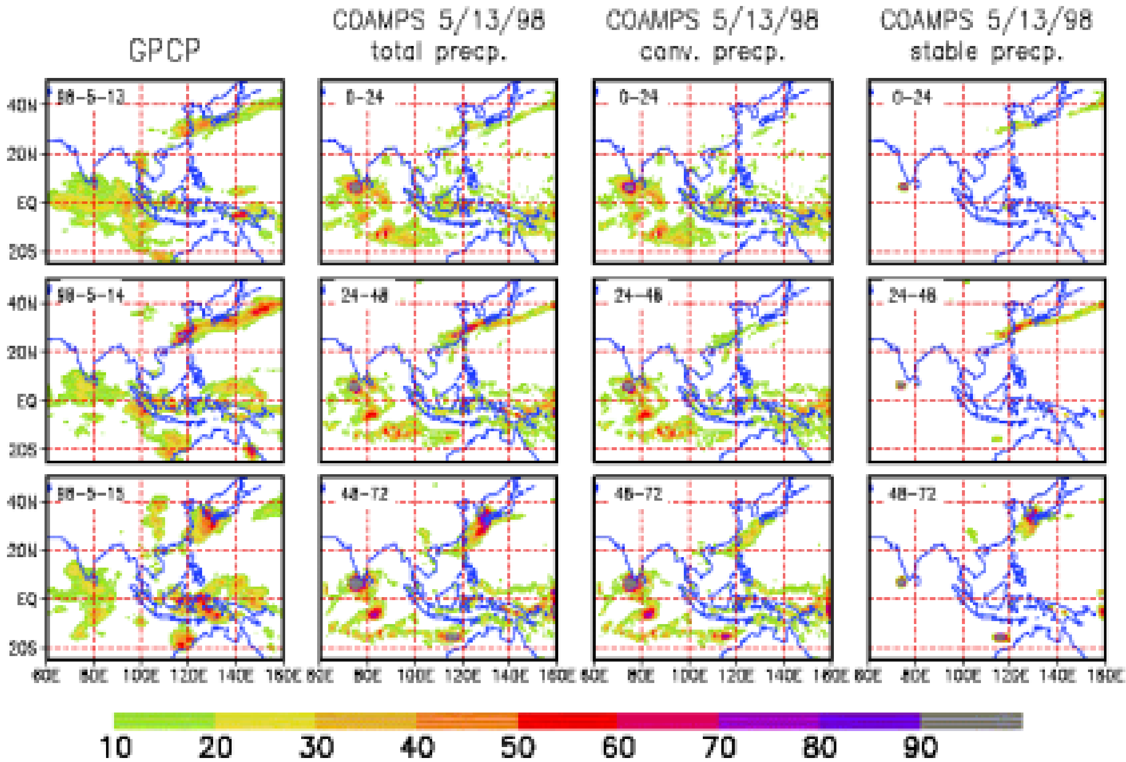

Fig. 1 Comparison of 24hr accumulated GPCP precipitation during May 13~May 15, 1998 (first column) with COAMPS forecasts of 0-24, 24-48 and 48-72 hr accumulated precipitation. The total, convective and stable precipitation of COAMPS forecast are shown in the second, third and fourth columns, respectively.

Fig. 1 also shows the development of a false ITCZ-like rain zone in the southeastern tropical Indian Ocean (80E-100E, 10S-15S). This rain zone appears in all experiments during the SCSMEX period of 5/9/98-5/24/98 regardless of actual observation, which often shows little or no precipitation in the region. Therefore it is likely a systematic error of the COAMPS model. Possible roles of sea surface temperature data on this error are being investigated.

The surface latent heat fluxes over elevated terrain during daytime are also significantly overestimated. In the afternoon the fluxes over the Tibetan Plateau even exceeds that over the surrounding tropical ocean. This is unrealistic and a major problem for the monsoon onset simulations. We experimented with the ground moisture equation and reduced of the surface latent heat fluxes over land sufficiently to decrease the 24 hr accumulated precipitation to by more than 5% over the entire model domain. Further experimentation will still be required to resolve this problem.

2. Development of tropical synoptic scale disturbances in the western Pacific monsoon region

The interactions between monsoon circulations and tropical disturbances in the Northwest Pacific, where the low-level mean flow is westerly in the west and easterly in the east, are studied with a barotropic model. Our results suggest that the scale contraction by the confluent background flow, the nonlinear dynamics, the β effect, and the large-scale convergence are important for the energy and enstrophy accumulation near the region where the zonal flow reverses. The energy/enstrophy accumulation can be maintained with a continuous Rossby wave emanation upstream. The largest accumulation occurs when the emanating zonal wavelength is around 2000 km. Longer Rossby waves experience less scale contraction and nonlinear effects while shorter Rossby waves cannot hold a coherent structure against dispersive effects.

In a more realistic monsoon-like background flow integration, a northwestward propagation pattern with an approximately 8-day period and 3000 km wavelength is produced, in general agreement with observed disturbances in the tropical Northwest Pacific. The intensified disturbance may disperse energy upstream, leading to a series of trailing anticyclonic and cyclonic cells along the northwestward propagation path. When an opposing current is present, the energy dispersion leads to the formation of new disturbances in the confluence zone by an vortex axisymmetrization dynamics. Thus, our results indicate that the scale contraction and nonlinear effects may cause a succession of tropical disturbances to develop without disturbance-scale diabatic effects.

IMPACT

Analysis of tropical forecast experiments of COAMPS during SCSMEX resulted in the discovery of coding bugs and model deficiencies. Research is underway to address these deficiencies. The dynamical modeling of the interactions between tropical west Pacific monsoon region and synoptic scale disturbances revealed a possible mechanism for the development of tropical vortices (cyclones) from weak synoptic scale disturbances.

TRANSITIONS

A bug that caused an overestimate of precipitation was discovered in subroutines "kfdrive.F" and "kfpara.F" of COAMPS, where convective precipitation is calculated. The bug has been reported to model developers at NRL for correction. In using the model for monsoon studies we assess the skill and characteristics of the models and the suitability of different physical parameterization schemes in forecasting over the monsoonal region from western Pacific to Indian Ocean, and find clues that may be useful for model improvement efforts.

RELATED PROJECTS

Joint work with NSF Project on Asian Monsoon at NPS. The NSF project conducted observational and theoretical studies of the Asian monsoon motions and complements the numerical modeling efforts of this project.

SUMMARY

The COAMPS study was one of the first using Navy's operational regional model in the tropical-monsoon region from Indian Ocean to western Pacific, where proper representation of cumulus convection effects is a difficult challenge for the model. The results revealed specific and significant problems of the model that need be addressed. Our dynamic modeling study also brought out a possible mechanism for the development of tropical vortices from large-scale tropical flows. This is a major problem in tropical cyclone meteorology, as previous explanation of tropical cyclone development mostly depend on the release of latent heat, which is usually significant only after the development is already underway.

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Kuo, H. C. and C.-P. Chang, 2001: Tropical Vortex Development in Northwest Pacific monsoon. International Scientific Conference on SCSMEX, April 2001, Shanghai.