Western Pacific Tropical Cyclone Reanalysis with the NRL Atmospheric Variational Data Assimilation System (NAVDAS)

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LONG-TERM GOALS

The long-term goal of this project is to improve the prediction of tropical cyclone (TC) genesis, structure and intensity changes through improved initial condition and data assimilation technique. Accurate prediction of TC genesis, structure and intensity changes is critical to Navy missions and civilian activities in coastal areas. Due to sparse observational coverage over the open ocean, a key element of typhoon data assimilation is how to assimilate the latest satellite products such as Advanced Microwave Sounding Unit (AMSU), AIRS, and SSMIS in to the model initial condition. These new satellite products provide high-resolution 3-dimessional temperature and moisture fields and rain rate profiles. By assimilating the satellite radiance data, we enhance the NAVDAS capability and thus improve NOGAPS and COAMPS TC and weather forecast.

OBJECTIVES

The objective of this project is are to develop a suitable strategy for TC initialization using NAVDAS in the Navy Coupled Ocean-Atmosphere Mesoscale Prediction System (COAMPS) with application of latest satellite products and a variational data assimilation scheme and to construct a comprehensive, high-resolution reanalysis dataset for TCs in the western Pacific and provide the dataset to TC community.

APPROACH

Our strategy is to run reanalysis procedures using various observational data including satellite products (e.g., AMSU-A/B brightness temperatures/radiances, scattermeter winds, SSM/I total precipitable water and rain rate, polar-orbiter and geostationary feature-track wind), radiosonde, surface land, surface marine and flight-level observations, and combine these observations with the COAMPS or WRF model

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14. ABSTRACT
The long-term goal of this project is to improve the prediction of tropical cyclone (TC) genesis, structure and intensity changes through improved initial condition and data assimilation technique. Accurate prediction of TC genesis, structure and intensity changes is critical to Navy missions and civilian activities in coastal areas. Due to sparse observational coverage over the open ocean, a key element of typhoon data assimilation is how to assimilate the latest satellite products such as Advanced Microwave Sounding Unit (AMSU), AIRS, and SSMIS in to the model initial condition.

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dynamics in order to retrieve dynamically balanced TC wind, pressure, moisture and temperature fields. We propose to use the NRL NAVDAS and compare its data assimilation results with those from the WRF 3DVAR/4DVar assimilation system for 2005-2007 western North Pacific TC cases.

WORK COMPLETED

Collaborating with NRL data assimilation team (Dr. Nancy Baker and Dr. Bill Campbell), we are currently improving NAVDAS radiance assimilation techniques using the community radiative transfer model (CRTM). The improvement of satellite (AMSU_B, SSMIS and AIRS) radiance assimilation is crucial for typhoon data assimilation as in the western Pacific open ocean, aircraft observations are limited, and satellite products are major data sources for assimilation. A formal agreement between NRL and UH was signed in September 2008, regarding the release of NAVDAS codes to the UH research group.

In addition to the data assimilation effort, we have conducted several research topics related to tropical climate and tropical meteorology, including precursor conditions of tropical cyclone formation, TC Rossby wave energy dispersion under 3D mean flows, and the interaction between the TC core and asymmetric perturbations.

RESULTS

High-resolution satellite data and NCEP-NCAR reanalysis data are used to analyze 34 TC genesis events in the western North Pacific (WNP) during its 2000 and 2001 typhoon seasons. Three types of synoptic-scale disturbances are identified in the pre-genesis stages that can be linked to TC genesis. They are tropical cyclone energy dispersion (TCED), synoptic wave trains (SWT) that are not associated with pre-existing TCs and easterly waves (EW). Among the total 34 TC genesis cases, six are associated with TCED, eleven cases are associated with SWT and seven cases are associated with EW. Our analyses indicate that the occurrence of TCED depends on the intensity of the previous TC and the background flow, with stronger cyclones and weaker background easterlies more likely to induce a Rossby wave train. Still, not all Rossby wave trains would lead to the formation of a new TC. Among the eleven SWT cases, four cases are triggered by equatorial mixed Rossby-gravity waves. Cyclogenesis events associated with EW are identified by westward propagation of perturbation kinetic energy and precipitation fields. For all three types of pre-storm disturbances, we suggest that scale contraction of the disturbances and convergence forcing from the large-scale environmental flow are possible mechanism leading to the genesis. Tropical intraseasonal oscillations have a significant modulation on TC formation, especially in

2000. Further examination of the remaining 10 genesis cases with no significant prior synoptic-scale surface signals suggests three additional possible genesis scenarios: 1) disturbance with upper-tropospheric forcing, 2) interaction of a preexisting TC with southwesterly monsoon flows, and 3) preexisting convective activities with no significant initial low-level vorticity.

The difference between the observed AMSU-B brightness temperature and the brightness temperature assimilated by CRTM is defined as the observation residual. Figure 1 indicates that the peak value for counting of the observation residual is near zero after the bias correction. Thus, the distribution of the observation residual is closer to a normal Gaussian distribution after the bias correction.

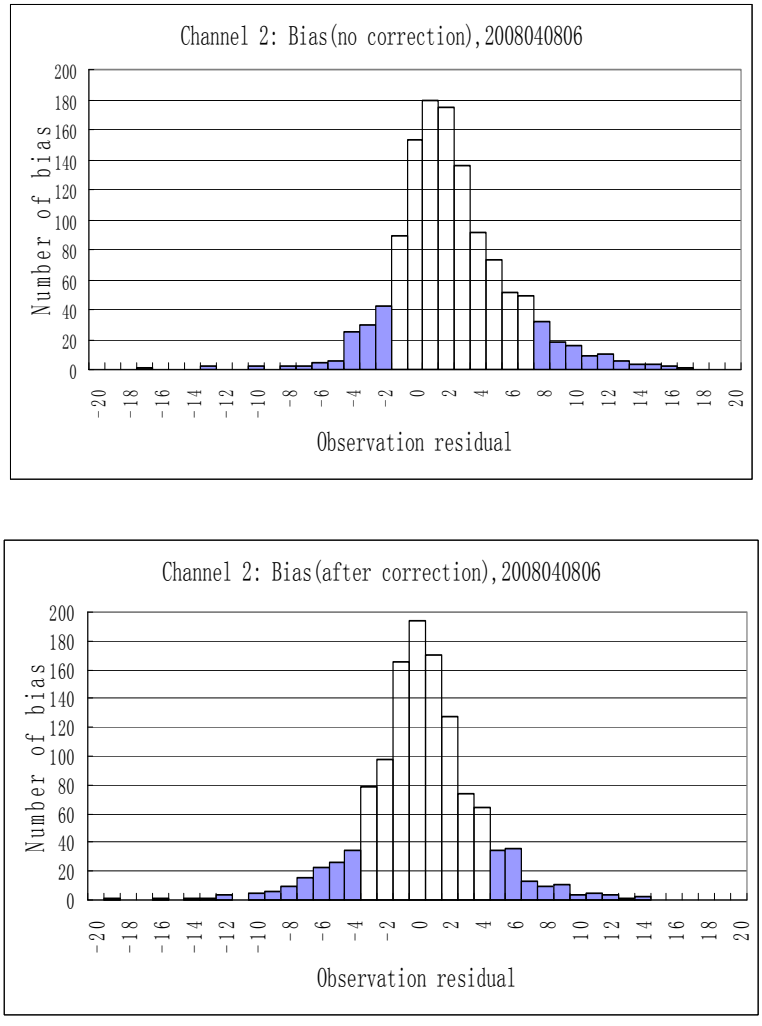

Fig. 1 Histogram of the observation residuals before (left) and after (right) the bias correction for AMSU-B Channel 2 at 0600UTC 08 April 2008

Tropical cyclone Rossby wave energy dispersion under easterly and westerly vertical shears is investigated in a baroclinic model. In a resting environment, the model simulates a Rossby wave train that has a realistic baroclinic structure with alternating cyclonic-anticyclonic-cyclonic (anticyclonic-cyclonic-anticyclonic) circulations in the lower (upper) troposphere. A significant asymmetry appears in the wave train development under easterly and westerly vertical shears, that is, an easterly (westerly) shear confines the maximum amplitude of the wave train primarily to the lower (upper) level. It is proposed that the vertical wind shear may impact the Rossby wave train development through both the barotropic-baroclinic mode coupling and the modulation of the group velocity by the mean flow through a "Doppler shift effect". Additional experiments with uniform westerly and easterly mean flows are conducted to verify the above mechanisms. The enhancement of the Rossby wave train in the lower level by the easterly shear may have an important implication for understanding the tropical cyclogenesis and the origin of the synoptic wave trains in the western North Pacific.

IMPACT/APPLICATIONS

The application of satellite radiance data assimilation in NAVDAS is critical to improve the NOGAPS and COAMPS predictions of tropical cyclones and weather in general. The proposed TC reanalysis project will provide valuable datasets for TC basic research and enhance the application of satellite observations. The methodology applied here may be applied to real-time operational predictions, leading to the improvement of TC intensity forecast. It may help generate near real-time products of detailed 3D TC structures for disaster estimation and water resource management.

TRANSITIONS

The improved AMSU-B radiance assimilation code has been delivered to NRL data assimilation group for further test and possibly for future operational use.

RELATED PROJECTS

This project is closely related to the ONR funding entitled "Analysis and high-resolution modeling of tropical cyclogenesis during the TCS-08 and TPARC Field Campaign". Knowledge gained from this project will help assimilate TCS-08 and TPARC observational data and improve the model (e.g., NOGAPS and COAMPS) initial condition for TC prediction.

PUBLICATIONS

In the following we list the publications that are fully or partially supported by this ONR grant:

Fu, B., T. Li, M. Peng, and F. Weng, 2007: Analysis of tropical cyclone genesis in the western North Pacific for 2000 and 2001. *Weather Forecasting*, 22, 763-780.

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