Using NOGAPS Singular Vectors to Diagnose Large-scale Influences on Tropical Cyclogenesis

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Grant Number: N000140810250
http://www.nrlmry.navy.mil/adap-bin/tcs_adap.cgi

LONG-TERM GOALS

The overarching goal is to provide an improved understanding of the synoptic-scale influences on tropical cyclone formation in the NW Pacific Ocean basin, in the context of error growth in forecast models. Benefits to the Navy would include improved forecast skill of developing tropical cyclones.

OBJECTIVES

To connect NOGAPS Singular Vector perturbation growth to synoptic-scale dynamical influences on tropical cyclone formation and structure change; and to evaluate the influence of assimilating TCS-08 observations into the Navy assimilation and forecast system, and investigate whether NOGAPS SV perturbations capture this influence.

APPROACH

Four significant tropical cyclones (TCs) formed during the TCS-08 field phase: Nuri, Sinlaku, Hagupit and Jangmi. The first stage of the research is the diagnosis of NOGAPS SVs associated with these storms. The real-time NOGAPS SV sensitivity guidance that was produced for developing systems in a region close to Guam (Fig. 1) during TCS-08 is currently being analyzed. If necessary, the NOGAPS SV guidance will be rerun by Co-PI Reynolds with a specific focus on verification regions centered on the developing systems. The dominant sensitivity patterns, evolving horizontal and vertical structure

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
30 SEP 2008	**Annual**	**00-00-2008 to 00-00-2008**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Using NOGAPS Singular Vectors To Diagnose Large-scale Influences On Tropical Cyclogenesis	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **University of Miami, RSMAS/MPO,,4600 Rickenbacker Causeway,Miami,FL,33149**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
code 1 only

14. ABSTRACT
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15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**3**	

and error growth will be investigated for these cases, from the formation stage through to typhoon status. The connection between these perturbation structures and synoptic-scale processes influencing developing tropical cyclones will be investigated, expanding upon the case study of Yamaguchi et al. (2008) for a single typhoon. In addition to the regular dry SVs, moist SVs will also be computed and analyzed for interesting cases.

The second stage of the project is to evaluate the effectiveness of dropwindsonde observations on NOGAPS predictions of tropical cyclone formation and structure change, via "data denial" in the NOGAPS/NAVDAS framework. The dropwindsondes from the USAF C-130, NRL P-3, DOTSTAR and Falcon aircraft will be used, as will those released from driftsonde balloons in areas of high SV sensitivity. The modification to the NOGAPS synoptic fields due to the special TCS-08 and T-PARC observations will be analyzed and compared with the SV structures, elucidating the effectiveness of the SV structures in accounting for perturbation growth in global models.

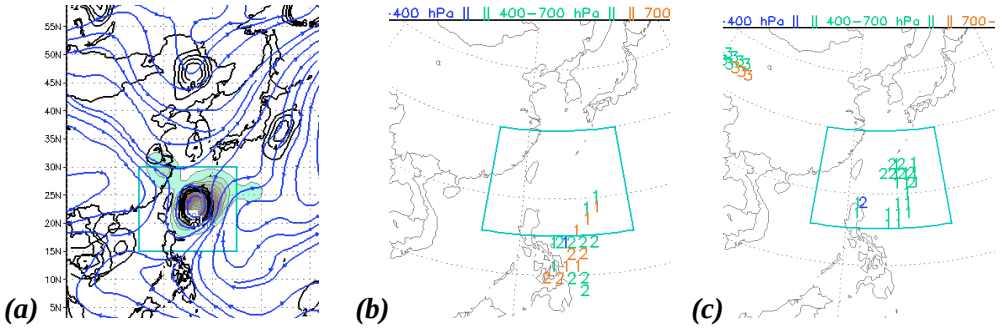

FIGURE 1. NOGAPS Singular Vector sensitivity guidance for system TCS033, which developed into Typhoon Sinlaku. The NOGAPS SVs were initiated on 00 UTC September 9th 2008, and SV growth between 00 UTC 10th and 00 UTC 12th was optimized. (a) integrated total energy of the leading 3 initial-time SVs; (b) sensitivity to vorticity in each of the first 3 SVs (denoted by number on map); (c) sensitivity to temperature in each of the first 3 SVs.

WORK COMPLETED

In Year 1, the primary task was to provide real-time NOGAPS SV sensitivity guidance for targeted observations during the TCS-08 field phase. Co-PI Reynolds provided this guidance daily (and sometimes twice daily) for a variety of verification regions, encompassing formation, structure change, recurvature and extratropical transition. Daily summaries of the SV guidance were prepared under the "Weather Targeting Blog" section on the EOL catalog. For example, Figure 1 illustrates the overall sensitivity for Sinlaku being associated with the subtropical ridge, with sensitivity to mid-lower level vorticity perturbations on the south-east side, and mid-level temperature perturbations towards the east of Sinlaku. Prof. Majumdar and his new graduate student, Munehiko Yamaguchi, spent 3 and 2 weeks respectively at the TCS-08 Operations Center in Monterey. When a storm was present, they coordinated the Elluminate sessions on targeted observations, synthesizing a wide array of products on predictability and targeting to facilitate decisions on aircraft deployment. The presentations accompanying these sessions are archived in the "Weather Targeting Blog" section on the EOL catalog. These products are now being reviewed retrospectively by the U.Miami and NRL Monterey teams to identify key cases for in-depth investigation in Years 2 and 3.

An undergraduate student at the University of Miami, Peter Finocchio was paid $1000 from this grant to investigate multi-model ensemble forecasts, and their uncertainty in capturing TC formation and track. A paper will be submitted within the next year. Via matching salary for his summer work and a travel grant from U. Miami, Peter spent 17 days at the TCS-08 Operations Center to assist the TCS-08 team with weather briefings.

Additionally, Dr Eric Rappin, an assistant scientist funded partially by a different ONR TCS-08 grant (N000140810251; PI Velden) has been training Majumdar and Yamaguchi on how to run a 2-km resolution version of the Weather Research and Forecasting (WRF) model, including a bogus vortex initialization. This high-resolution model can be nested within NOGAPS output to answer questions about tropical cyclone *structure change.*

RESULTS

Some general conclusions can be drawn via inspections of the NOGAPS SV guidance for mature tropical cyclones. For example, sensitivity is usually on the eastern and southern side of the cyclone, corresponding to the periphery of the subtropical ridge influencing the cyclone's motion and wind field, and to the north and north-west, associated with the interaction with an approaching shortwave trough. These results are consistent with those found in earlier studies by Co-PIs Peng and Reynolds. However, for formation, which is the primary and most novel focus of this project, the cases need to be investigated in more detail since the sensitivity appears less intuitive on first inspection.

IMPACT/APPLICATIONS

The scientific impact will be an improved understanding of the underlying environmental mechanisms that influence tropical cyclone formation. This understanding will be coupled with a quantitative knowledge of error growth in global models, via SVs. The SVs also possess practical value in that they can be used in future targeting applications, with the augmentation of the routine observational network with new aircraft, balloon and satellite-based observations to improve Navy forecasts of typhoon formation and structure change.

RELATED PROJECTS

This project is related to that funded by the TCS-08 grant N000140810251: "Advanced Satellite-Derived Wind Observations, Assimilation, and Targeting Strategies during TCS-08 for Developing Improved Operational Analysis and Prediction of Western North Pacific Tropical Cyclones", on which Majumdar is a Co-PI. The NOGAPS Singular Vectors will also be used as a targeting strategy in this TCS-08 grant.

PUBLICATIONS

Yamaguchi, M., T. Iriguchi, T. Nakazawa and C.-C. Wu, 2008: An observing system experiment for Typhoon Conson (2004) using a singular vector method and DOTSTAR data, *Mon. Wea. Rev.*, accepted.