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MODIS WINDS IN NAVDAS

Patricia M. Pauley*
Naval Research Laboratory, Monterey, California

Randal L. Pauley
Fleet Numerical Meteorology and Oceanography Center, Monterey, California

1. INTRODUCTION

Feature-track winds from geostationary satellites have long been an important type of meteorological data for operational Numerical Weather Prediction (NWP). Winds from the five geostationary meteorological satellites provide nearly global horizontal coverage, except for polar regions. Since the subpoints of these satellites are over the equator, polar regions are either in or near the limb where parallax becomes a significant issue. Consequently, the Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin-Madison has applied their feature-track wind algorithms to the data from the MODIS (MODerate-resolution Imaging Spectroradiometer) instrument on board the NASA EOS Terra and Aqua polar orbiting satellites. By tracking features from consecutive swaths of data, they generate feature-track winds at polar latitudes.

The procedures for generating feature-track winds from MODIS data are detailed in Santek et al. (2002). To summarize, MODIS imagery in the 11 μm infrared and 6.7 μm water vapor channels is remapped on a polar stereographic projection, and standard feature-tracking procedures are applied to derive winds poleward of 60°. Height assignments utilize model temperature profiles from the Navy Operational Global Atmospheric Prediction System (NOGAPS).

MODIS winds are subject to the same types of errors as those from geostationary satellites, as well as errors associated with the longer time between images (100 min for MODIS vs. 30 min for geostationary satellites), differences in parallax between successive swaths, and increased difficulty in height assignments associated with meteorological conditions at polar latitudes. Even so, the European Center for Medium Range Weather Forecasts (ECMWF) has demonstrated increased forecast skill associated with the use of MODIS winds not only in polar regions but also in the extratropics (Santek et al. 2002; Bormann and Thepaut 2003).

This paper describes the methodology used to assimilate MODIS winds in the NRL (Naval Research Laboratory) Atmospheric Variational Data Assimilation System (NAVDAS) as well as preliminary forecast results from NOGAPS. Plans for future tests are also described.

2. MODIS WINDS IN NAVDAS

NAVDAS is a three-dimensional variational data assimilation system cast in observation space that was developed at the Naval Research Laboratory-Monterey. Details of the algorithm and its implementation are described in Daley and Barker (2001). NAVDAS was transitioned for operational use at Fleet Numerical Meteorology and Oceanography Center (FNMOC) on 1 October 2003. The use of MODIS winds was not included in the original implementation.

In NAVDAS, MODIS winds are superobbed in the same manner as feature-track winds from geostationary satellites (Pauley 2003). Observations are binned into 2° "prisms" with a depth of 50 mb. Each prism has a height of 2° latitude and a width that varies by latitude to give roughly square areas and an integer number of prisms in a latitude band. Superobs are required to have two or more observations that are consistent with each other after possibly rejecting one or two outliers. Consistency is defined here as wind speeds within approximately 7 m/s, and either u and v components within 5 m/s or wind directions within 20°. If the observations in a prism do not pass the consistency test even after rejecting outliers, no superob is formed. The superobs are formed by averaging the available innovations (observation minus background) and are used at the average location. A kinetic energy adjustment is applied to ensure that the resultant speed and mean speed are the same. In the initial tests reported here, all available MODIS winds were presented for superobbing. Neither horizontal nor vertical limitations were placed on the MODIS winds,

* *Corresponding author address:* Patricia M. Pauley, Naval Research Laboratory, 7 Grace Hopper Ave., Monterey, CA 93943; e-mail: pauley@nrlmry.navy.mil.

nor were any winds rejected based on the quality indices provided by CIMSS.

3. RESULTS

Results are presented here from a three-week test encompassing 10-30 October 2003. The control and MODIS runs differ only in the inclusion of MODIS winds. Both use NAVDAS to assimilate the data available operationally at FNMOC—rawinsonde, surface (from land stations, ships and buoys), aircraft (both voice and automated reports), feature-track winds from geostationary satellites, ATOVS temperature profiles, and SSM/I total precipitable water. (The use of SSM/I surface wind speeds and QuikSCAT surface winds in NAVDAS will be tested in the near future.) And, both use the operational configuration of NOGAPS (Hogan et al. 2004) to perform 5-day forecasts. Results from forecasts initialized at 0000 UTC are presented in the figures below.

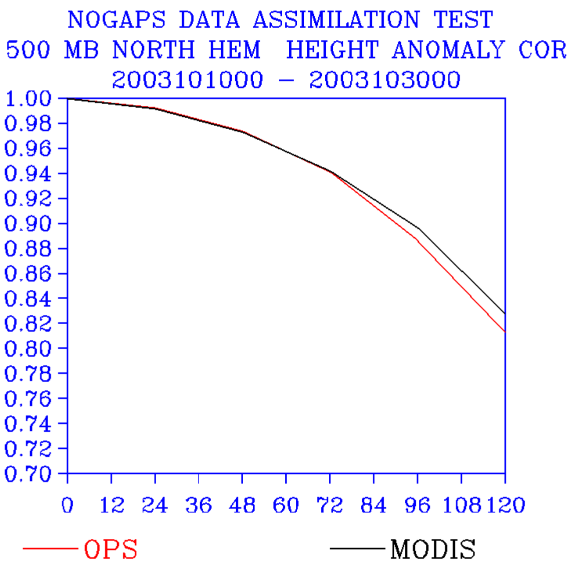

Figure 1: *Average Northern Hemisphere 500 mb height anomaly correlations as a function of forecast range (hours) for the NOGAPS MODIS and control (OPS) tests.*

The results from this test are similar to those found by ECMWF. Figure 1 shows the mean 500 mb height anomaly correlations over the Northern Hemisphere for the test period. This comparison shows that the inclusion of MODIS winds improves forecast skill for ranges beyond 72 hrs. In addition, the inclusion of MODIS winds improves forecast skill in both the Arctic region (defined as north of 60°N) (Fig. 2) and in the Northern Hemisphere mid-latitudes (defined as 20°N to 60°N) (Fig. 3). The differences in mid-latitudes are consistent with Bormann and Thepaut (2003). They document a case study where differences in the analysis in the Arctic region between ECMWF MODIS and control forecasts propagate downstream and lead to large differences over North America and the North Atlantic at Day 4.

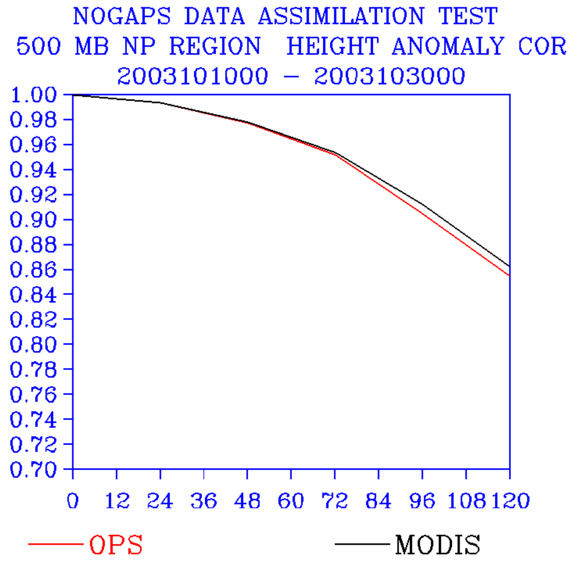

Figure 2: *Same as Figure 1 except for the Arctic region (north of 60°N).*

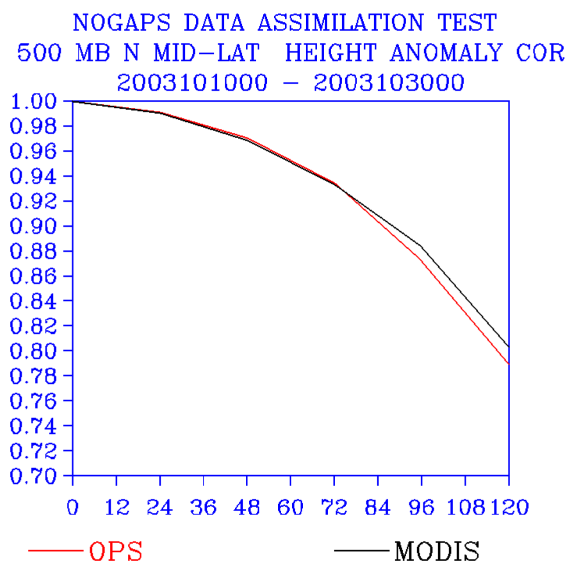

Figure 3: *Same as Figure 1 except for the Northern Hemisphere mid-latitude region (20°N to 60°N).*

MODIS winds did not have a positive impact on anomaly correlations for Southern Hemisphere forecasts. Bormann and Thepaut (2003) found a neutral impact for the inclusion of MODIS winds in the ECMWF system in the Southern Hemisphere. They speculated that this might result from poorer height assignments over the high terrain of the Antarctic, from the subsequent exclusion of MODIS winds below 400 mb over land, and/or from fewer validating observations. Work is ongoing to investigate the differences in performance between the hemispheres in the NAVDAS/NOGAPS system.

4. SUMMARY

This paper presents preliminary results from a test of the impact of MODIS winds on NOGAPS forecasts. These winds were assimilated as superobs in the NAVDAS data assimilation system. These early results are quite promising in the Northern Hemisphere, but less so in the Southern Hemisphere. A follow-up test is planned to examine the effect making the quality control decisions more stringent. This test will exclude MODIS winds with QI scores less than 0.66—the current test included winds with QI scores as low as 0.60. In addition, MODIS winds equatorward of 65° will be excluded, along with winds above 275 mb and water-vapor winds below 575 mb. The goal of these tests is to determine a configuration for the MODIS winds that will be implemented in the operational version of NAVDAS.

An interesting ramification of using MODIS winds operationally is that they will then influence the NOGAPS analyses and forecasts that are used by CIMSS in the original height assignments for the MODIS winds. While the outcome is by no means certain, it is to be hoped that improving the NOGAPS analyses and forecasts will help improve the MODIS height assignments. Daniels et al. (2003) show examples where MODIS winds differ significantly depending on whether a NOGAPS or a GFS (Global Forecast System) forecast is used in determining height assignments, suggesting that there is room for improvement in this area.

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