IMPACT OF MODIS WINDS ON DAO SYSTEMS

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ABSTRACT

A one-month experimental MODIS winds dataset is available to provide wind information for the high-latitude regions where there are very few direct satellite or conventional wind observations. The MODIS winds dataset is successfully assimilated, and its impact on the Goddard DAO data assimilation system is investigated. The initial results indicate an immediate positive impact from the MODIS data in the high-latitude regions of both hemispheres, and a simple interactive height adjustment is found to further increase the positive impact of the data in the southern hemisphere.

1 Introduction

It is widely recognized that the lack of independent information about the vertical wind profile in the free atmosphere away from the regions of good observation coverage is a major cause of larger than normal forecast errors, or "busts". Direct wind observations, i.e. information about the atmospheric flow that is not derived from the mass field, therefore remains high on the list of priorities for operational numerical weather prediction (NWP). In general, there are very few wind observations at the high latitudes (beyond 60^o), especially in the southern hemisphere. With the launch of NASA's Moderate-resolution Imager/Sounder (MODIS), high-resolution imagery has been become available at an image navigation accuracy that allows for the testing of the geostationary wind algorithms on high-latitude imagery obtained from polar orbiters. A one-month pilot dataset consisting of winds derived from MODIS 6.7μ and 11μ images has thus been generated at CIMSS and made available to the NWP community (Key et al. 2002). In this note we present results from the initial evaluation of this dataset in the context of a global data assimilation system.

2 Experimental setup and results

(1) Brief introduction of fv-DAS

The experiments discussed here are conducted using version 1.2 of the newly developed finite-volume data assimilation system (fv-DAS) of the Goddard Data Assimilation Office (DAO). The fv-DAS consists of a finite-volume general circulation model (fvGCM; Lin and Rood 1996, 1998), a Statistical On-line Quality Control System (SOQCS), and the Physical-space Statistical Analysis

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System (PSAS; Cohn et al. 1998). The fvGCM has a horizontal resolution of 1^o latitude by 1.25^o longitude and 55 vertical levels, and the analysis increment is computed by the PSAS algorithm at about half this resolution (2×2.5^o and 25 levels).

(2) Experimental setup

In order to study the impact of the MODIS winds on data assimilation and forecast skills, four experiments are carried out over the MODIS winds test period of March 5, 2001 to April 4, 2001. The first experiment, the control, consists of a regular data assimilation run including all standard observations (radiosondes, aircraft measurements, conventional surface data, HIRS/AMSU temperature and humidity profiles, geostationary winds, Q-SCAT surface winds and SSM/I total precipitable water), but not including the MODIS winds. The second experiment, the so-called WV experiment, includes the MODIS wind observations "as is", using the original height assignment of the winds provided by CIMSS. The third experiment, referred to as WV_h_1, includes the MODIS winds, modified by interactively reassigning the heights of the winds based on our own first guess field, as described below.

Similar to the quality control methodology used in UW-CIMSS (Olander, 2001) for MODIS winds, the heights of MODIS winds are adjusted by minimizing a penalty function, which measures the discrepancy between the MODIS data and the fv-DAS first guess. The penalty function **J** is defined as:

$$\mathbf{J}_m = \left(\frac{u_m^o - u_m^f}{F_u}\right)^2 + \left(\frac{v_m^o - v_m^f}{F_v}\right)^2 + \left(\frac{T_m^o - T_m^f}{F_T}\right)^2 + \left(\frac{P_m^o - P_m^f}{F_P}\right)^2, \tag{1}$$

where u and v are the zonal and meridional components of wind vector, T is the temperature or satellite brightness temperature which is calculated from the satellite imagery radiance measurement, and P is the pressure altitude of the wind vector. The subscript m denotes the observation location, and the superscripts o and f denote the observation data and the interpolated fv-DAS first guess at the observation location. The weighting factors F_u, F_v, F_T, and F_P take the values 2.0 ms^{-1}, 2.0 ms^{-1}, 10.0^oC, and 100.0 hPa as in UW-CIMSS (Olander, 2001).

In the WV_h_1 experiment, the allowed maximum height adjustment is 150 hPa, and any MODIS wind vector with velocity discrepancy larger than 14.0 ms^{-1} or temperature discrepancy larger than 20.0^oC is left unchanged without height adjustment. The fourth experiment, referred to as WV_h_2, is similar to WV_h_1 experiment, except that the allowed maximum height adjustment is 75 hPa, and any MODIS wind vector with velocity discrepancy larger than 8.0 ms^{-1} or temperature discrepancy larger than 10.0^oC is left unchanged.

3 Experimental results

One of the main potential advantages of the MODIS winds is that they may contain valuable information about the flow at latitudes where no other wind observations are available. At the same time this lack of data also poses a problem for the validation of these new observations. In the context of this work, the impact of MODIS winds is therefore evaluated mainly by comparing the analysis fields with and without MODIS winds, and by comparing the respective skills of the forecasts launched from these analyses.

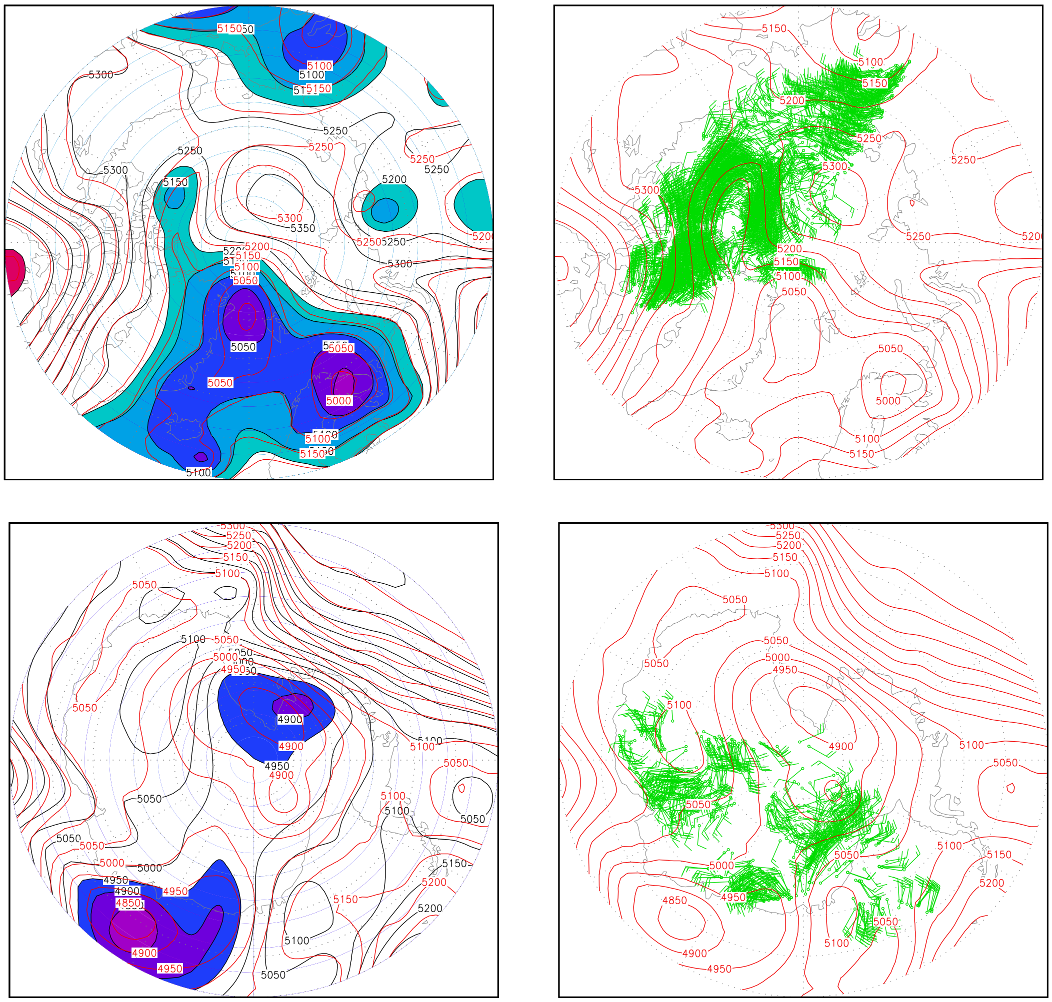

Figure 1: Comparison of the analyses between ECMWF (shaded black contour) and the control experiment (red contour) (left panels) and the WV experiment analysis superimposed by MODIS winds (right panels) at 500 hPa at 0Z March 5, 2001 for the northern (upper panels) and southern (lower panels) high-latitude regions.

As a qualitative illustration of the impact of the MODIS winds, we first show 0Z analyses for March 5, 2001 (Fig. 1) for the northern (upper two panels) and southern (lower two panels) high-latitude regions. These are the first analyses including the MODIS winds. The left panels show the 500 hPa geopotential hight analysis from the control experiment (red contour) where the ECMWF analysis (shaded black contour) is taken as an external validation source, and the right panels show the 500 hPa geopotential hight analysis from the WV experiment (red contour) superimposed by the MODIS winds. The analyses from the WV_h_1 and WV_h_2 experiments are very similar to those in WV experiment and hence are not shown here. It is clearly seen that the MODIS data lead to a substantially different analysis of trough northwest of Greenland. It also appears that including the MODIS winds generally helps draw the analysis of the WV experiment closer to the ECMWF analysis over the region where MODIS winds are available. Moreover, it can be seen that the geopotential height contours in the WV analysis line up well with the MODIS winds. These are all indications that the MODIS winds seem to represent a reasonable mix of expected and new information, and that the wind field they depict seem to make meteorological sense.

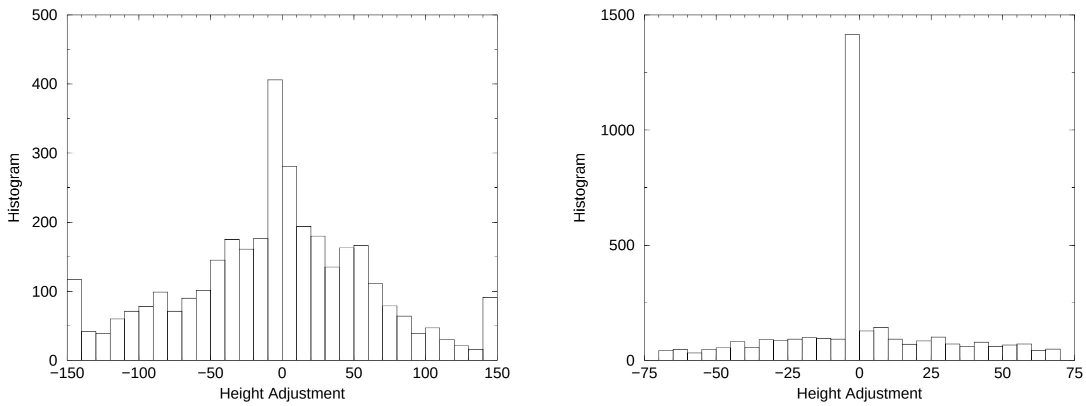

Figure 2: The histogram of height adjustment of MODIS wind data in the experiments WV_h_1 (left panel) and WV_h_2 (right panel) at 00Z March 5, 2001.

The RMS gridded differences between the MODIS water vapor/IR zonal winds and the first guess (i.e. 6-hour forecast winds) as a time series over the initial 30-day MODIS wind period are calculated (Figures not shown). All three experiments using MODIS winds are characterized by having smaller MODIS winds-minus-forecast (OmF) residuals. In other words, assimilation of the MODIS winds substantially reduces the short-range forecast error, when validating against the MODIS winds themselves. Similar results are found for the meridional component of the wind (not shown). It is also found that the OmF is further reduced in the experiments where the heights of MODIS winds are re-assigned interactively using fv-DAS's first guess. From their corresponding histograms of height adjustments at 0Z March 5, 2001 (Fig. 2, left panel for WV_h_1 and right panel for WV_h_2), it can be seen that, WV_h_1 experiment performs a much more aggressive adjustment on the heights of the MODIS winds than WV_h_2 experiment, and the WV_h_2 experiment basically performs a minor adjustment or no adjustment for most of the MODIS winds.

The medium-range five-day forecast skill is used as an additional metric of the impact of the MODIS winds. A 10-year climatology from the ECMWF operational analyses (1988 through 1997) is used for the calculation of anomaly correlation coefficients. Since few observations are available in the high-latitude regions for the control experiment, forecast skills for the control experiment verified against its own analysis are therefore not presented here. The anomaly correlations of the 500 hPa geopotential height field are presented in Fig. 3 for the northern (left panel) and southern (right panel) high-latitude regions. All forecasts are verified against the analyses of the respective assimilation experiment. The results show that WV and WV_h_2 have higher forecast skills in the northern high-latitude region, but WV_h_1 has higher forecast skills in the southern high-latitude regions. This results seems to indicate that the original height assignment of the wind is subject

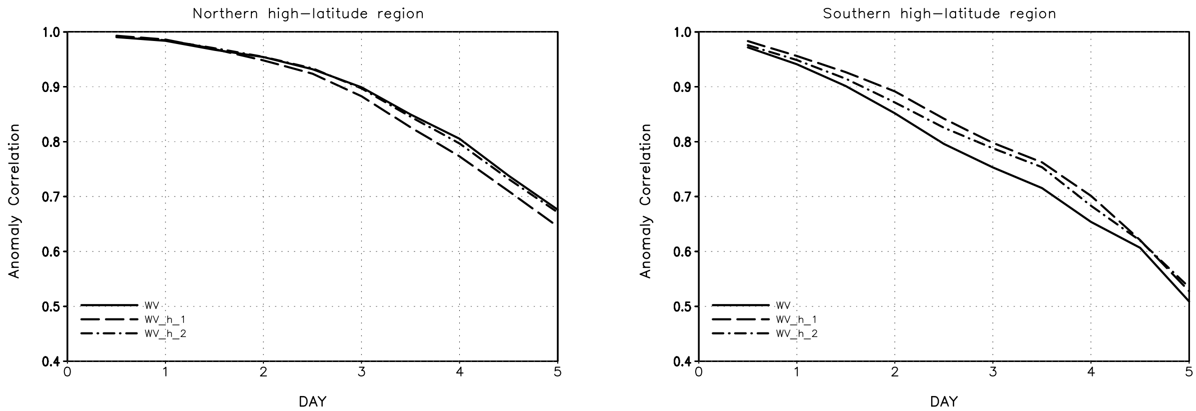

Figure 3: Anomaly correlations for 500 hPa geopotential heights in the northern (left panel) and southern (right panel) high-latitude regions for the WV (thick solid line), WV_h_1 (thick dashed line), and WV_h_2 (thick dot-dashed line) experiments verified against their own analyses.

to a larger error in the southern hemisphere.

In addition to the self-verification shown above, the forecast skill for an ensemble of 15 five-day forecasts is calculated using ECMWF operational analysis for verification. The anomaly correlations of the 500 hPa geopotential height field are shown in (Fig. 4, with left panel for the northern and right panel for the southern high-latitude regions). The results indicate that the experiments using MODIS winds are superior to the control experiment over both regions, and that the useful forecast range of experiments WV and WV_h_2 in the north and WV_h_1 in the south are extended by up to 12 hours compared to control. The 500 hPa wind RMS errors are calculated as well (Figures not shown). The experiments WV and WV_h_2 have the smallest RMS error in the northern high-latitude region, while WV_h_1 is the best in the south up to day four.

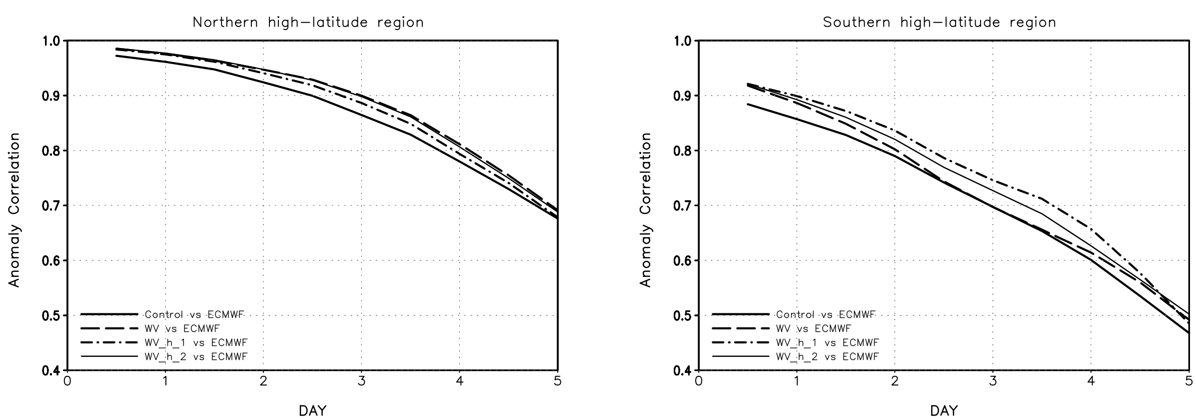

Figure 4: Anomaly correlations for 500 hPa geopotential heights in the northern (left panel) and southern (right panel) high-latitude regions for the control (thick solid line), WV (thick dashed line), WV_h_1 (thick dot-dashed line), and WV_h_2 (thin solid line) experiments verified against ECMWF operational analyses.

4 Summary and conclusions

An experimental dataset consisting of wind vectors derived from MODIS IR and water vapor imagery has been assimilated at the DAO, using a modern meteorological data assimilation system. In spite of the problems with the validation against independent data, the initial results are very encouraging. By standard assimilation metrics, there is an immediate positive impact from the MODIS data in both hemispheres. As for any type of atmospheric motion vector produced by feature tracking in image data, the correct assignment of heights is problematic. A simple interactive height adjustment was tested for the MODIS data. This was found to further increase the positive impact of the data in the southern hemisphere.

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