AN UPDATE ON UW-CIMSS SATELLITE-DERIVED WIND DEVELOPMENTS

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ABSTRACT

Several new upgrades have been incorporated into the University of Wisconsin - Cooperative Institute for Meteorological Satellite Studies (UW-CIMSS) satellite wind retrieval algorithm, which is used by NOAA/NESDIS for operational winds production. These upgrades include cloud masking, dual-pass objective quality control, improved water vapor and visible winds, and height assignment checks. In addition, new processing strategies are being studied including low-level cloud tracer (IR and VIS) retrieval and height assignments (cloud base), and temporal (more frequent) sampling intervals. All of these upgrades and studies are resulting in lower vector errors. Applications and recent model impact studies briefly outlined in this report show these advanced satellite-derived winds are having a notable impact on weather analysis and forecasting.

1. INTRODUCTION

UW-CIMSS is responsible for advances and upgrades to the satellite wind retrieval system used operationally by NOAA NESDIS. Since the previous International Winds Workshop, several upgrades to the processing software have been developed and tested at UW-CIMSS, and disseminated to NESDIS. The important upgrades are briefly described in Section 2. Section 3 discusses three new processing strategies that are being tested. The first involves new low-cloud height assignments based on earlier work by LeMarshall and Spinoso of the Australian Bureau of Meteorology. The method assigns cloud motions to the cloud base rather than cloud top. The second study involves improved targeting/tracking of low clouds in the IR channel. The third investigates the optimum image interval (temporal frequency) for tracking features in several spectral bands. Preliminary results are shown. Section 4 briefly summarizes recent field program applications and forecast impact results from assimilating the new advanced and enhanced wind fields into numerical weather prediction models. Finally, Section 5 suggests future directions.

2. RECENT PROCESSING SOFTWARE UPGRADES

A brief summary of major winds processing upgrades from UW-CIMSS is given below.

1) A cloud mask indicator is now determined and provided with the water vapor vector information. This parameter indicates whether features/winds tracked in water vapor channels are deemed as clouds or clear sky. The indicator is based on the success of the water vapor intercept method in determining the existence of semitransparent cloud in the target pixel array.

2) For vectors tracked in water vapor channels, the height assignment is determined by different methods depending on the above cloud mask indicator. For WV cloud-tracked winds, the water vapor intercept height method is used in semitransparent cloud conditions. In opaque clouds, the WV radiances (Tbb) are employed and matched to a model guess temperature profile for the height assignment. For clear sky WV winds, the Tbb mean of the immediate pixel array adjacent to the target (7 X 7 pixel array centered on max gradient location) is used.

3) Objective quality control is performed by the “auto-editor” in the final post-processing step of the UW-CIMSS algorithm. This method relies on a 3-dimensional objective analysis system, which has been empirically tuned over the years. The tuning was primarily set on the examination of large-scale datasets and environments. However, smaller scale dynamic regions (such as hurricanes or extratropical storms) needed to be treated separately since the objective editor contains an element of dependence on a model first guess, which may be erroneous in dynamic situations (especially oceanic events). Therefore, a dual-pass objective editing system was developed (Velden et al. 1998). Winds in identified regions (such as selected hurricanes) are quality controlled separately by passing the editor over these regions with looser constraints. The effect is to allow greater freedom for retaining vectors which differ from the first guess background. This step has resulted in a notable increase in the retainment of vectors around such features as hurricane outflows and high-speed jet streaks.

4) The water vapor intercept method is an effective tool for detecting cirrus cloud and tracers. However, there are many instances when, for various reasons, the method fails in thin cirrus cloud. The result is a vector height assignment that relies on IR-window or WV channel radiances that may alone not adequately represent the tracer height. Therefore, a method was developed which operates after the objective quality control step and re-examines each individual tracer with a height assignment above 500 mb that did not successfully attain a WV intercept height. The method checks neighboring vectors (currently, a 1.5-degree radius) for any that successfully passed the WV intercept procedure. The nearest successful vector is matched with the vector in question. If the vectors are in reasonable agreement (current empirically-derived thresholds are set at within 20 degrees for direction and 30% of the matched vector speed), the vector is assumed to be tracing undetected thin cirrus and its height is reassigned to the WV -intercept height of its neighbor. This procedure was tested over a large data sample and resulted in a .5 m/s decrease in overall vector rms error vs. collocated rawinsondes.

3. NEW PROCESSING STRATEGIES

Three new processing strategies are being studied with the aim of improving vector coverage and coherency. These are briefly outlined below.

1) The current method for processing IR cloud tracked winds invokes a spatial coherency test and gradient thresholding which improves the tracking of upper-level cirrus structures (Nieman et al. 1997). However, low cloud tracers become more difficult to obtain. The new procedure identifies low cloud regimes and disengages the spatial coherency check, and also adjusts (relaxes) the gradient thresholds. Preliminary results indicate a marked improvement in coherent low-level vector coverage from IR cloud tracking. This scheme is still under investigation.

2) Low-level cloud tracer height assignments have traditionally been placed based on IR-window Tbb methods. These methods estimate cloud top. However, studies have indicated that low level cumuliform cloud motion is best approximated by the wind at cloud base. A method was developed at the Australian Bureau of Meteorology to use histograms of the IR pixels in the target box, produce a Hermite polynomial expansion, and use the second derivative to identify/estimate the cloud bases. Preliminary tests indicate a mean lowering of vector height estimates associated with low clouds by an order of 40-50mb. Associated with this is a reduction of vector rms error (vs. collocated rawinsondes) of nearly .5 m/sec. This method is still under investigation, but will be implemented into the UW-CIMSS algorithm soon.

3) In order to examine the effects on tracer quantity/quality from more frequent imaging, winds were derived from GOES-10 full resolution imagery using the UW-CIMSS algorithms for one time period in April of 1998 during the GOES-10 science checkout test (nearly continuous 5 minute scans). For our evaluations, winds were produced using different image spacing at 5, 10, 15 and 30 minutes. Based on vector field quantity, quality (coherence), and match comparisons with collocated rawinsondes, the results indicate that the optimal time spacing interval between images varies per spectral band; visible is 5 minutes, IR and WV cloud tracked is 10 minutes, clear sky WV winds is 30 minutes. Operational and demonstrational processing currently uses 30 minute sampling for all bands. This initial result will be confirmed by a more comprehensive investigation involving testing over the entire 4-week test period.

4. APPLICATIONS AND IMPACT STUDIES

In this section, several applications of the high-density multispectral satellite winds are discussed. In addition, recent numerical model impact studies showing the positive impact of the satwinds are summarized.

Some recent applications include:

a) Real time use by the National Hurricane Center (NHC). Forecasters at NHC access the UW-CIMSS home page (http://cimss.ssec.wisc.edu/tropic/tropic.html) and download prepared GIF images of the satwinds at upper and lower levels in the vicinity of tropical storms. On several occasions the images have been referred to and publicly cited as defining important storm structure such as outflow or high wind radii.

b) The low-level cloud-tracked winds processed at UW-CIMSS from high resolution GOES visible imagery are disseminated to the Hurricane Research Division (HRD) in Miami. Researchers there have developed a real-time surface wind analysis of hurricane events. The GOES winds are adjusted to the surface using algorithms modified by UW-CIMSS (Dunion 1999), and incorporated into their analysis. Preliminary results are indicating the GOES winds are making positive impacts on the outer wind structure (i.e. radius of gale force winds (34 kts)). This is important information for emergency managers as storm landfall approaches.

c) Diagnostic fields are being derived from the recursive filter analyses produced from the high-density winds at UW-CIMSS. These fields include upper-level divergence and vertical wind shear. The products are being made available in real time and disseminated to national forecast centers such as NHC and the Joint Typhoon Warning Center (JTWC). Initial feedback is indicating the fields are being used in the operational analysis and forecast process and are making a difference in some cases (Pasch and Velden 1999). See the UW-CIMSS web site (tropical cyclones segment) for examples.

d) The satwinds are being disseminated to the National Weather Service Western Region forecast offices by NESDIS. The forecasters are using the vastly increased data over the Pacific Ocean to assess numerical model analysis accuracies, and fine tune operational forecasts.

Recent numerical model impact studies include:

a) In a research mode, GOES multispectral wind datasets were provided to the Geophysical Fluids and Dynamics Laboratory (GFDL) for input into their highly touted hurricane track forecast model. The GFDL model has achieved the greatest track forecast success over the past 5 years in the Atlantic Ocean. The satwinds were assimilated directly into the GFDL optimum interpolation analysis. For a sample of 30 cases, in which the GFDL model control runs (without the satwind data) were on average quite good, the GOES high-density winds produced at UW-CIMSS reduced the GFDL track forecast errors by 10-15% (Soden et al. 1999). Even more significant impacts are expected in forecast bust cases, such as Hurricane Bonnie of 1998, and this is being investigated.

b) The U.S. Navy operational model (NOGAPS) was used to test the impact of the GOES winds on numerical forecasts in the mid latitudes during FASTEX (Fronts and Atlantic Storms Experiment) in January-February 1997. The primary mission of FASTEX was to investigate objectively determined targeting strategies aimed at identifying areas of initial analysis deficiencies. Then introducing observations into those regions (i.e. aircraft dropsondes or enhanced sat data). Subsequent to the assimilation experiments run after the field data collection phase, the conclusions were that the addition of experimental high-density GOES winds to the initial analysis resulted in a reduction in forecast errors in all 5 cases examined, with 3 of them being significant reductions (Langland et al. 1998). The positive impact on a prescribed forecast error norm at forecast verification time (12-48hr) ranged from 1 % to 28%.

c) Another field experiment, the NORth Pacific EXperiment (NORPEX) in 1998 was designed to improve the 1-4 day operational forecasts of high-impact weather for the U.S., by providing targeted observations over the northeast Pacific Ocean. The enhanced GOES winds produced at UW-CIMSS and NESDIS/ORA/FPDT were again included in forecast impact experiments. Conclusions from the NORPEX organizers at a recent workshop were that possibly the most significant result of the experiment was the 20% reduction in 48 hr forecast error over the western U.S. with the inclusion of the enhanced GOES winds. This result was obtained using the U.S. Navy model, and was supported by further studies with the ECMWF global forecast system (see Rohn et al., this volume).

5. FUTURE DIRECTIONS

The recently demonstrated positive impact of the enhanced and advanced satwinds on National Weather Service applications, and the successful assimilation of field experiment datasets into NWP is encouraging. UW-CIMSS will continue to develop, fine-tune and advance the satwind processing algorithms and strategies, and feed them to NESDIS for operational implementation and upgrades. In addition, several areas will be getting research and development attention in the near future. UW-CIMSS will work with its partner at NESDIS/FPDT and other collaborators in the following areas:

- Investigation of new channels for feature tracking (GOES sounder, 3.9 micron, etc.).

- Focus processing strategies to the meso and climate scales. This will include investigations of rapid scans to mesoscale data retrieval, and reprocessing of historical data for climate reanalysis projects.

- Close collaboration with NWP scientists to optimize the assimilation of satwinds (Hoggatt et al. 1999).

- Development of vector characterization parameters and quality indicators based on objective techniques. Continuation of the collaboration between UW-CIMSS and EUMETSAT towards developing an integrated approach that utilizes the advantages of each QC method currently being employed at the respective sites (Holmlund et al., this volume).

- Begin observing system simulation experiments (OSSE) to demonstrate the potential for feature tracking using future observing platforms.

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