P1.10 DETERMINATION OF WIND VECTORS BY TRACKING FEATURES ON SEQUENTIAL MOISTURE ANALYSES DERIVED FROM HYPERSPECTRAL IR SATELLITE SOUNDINGS

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1. INTRODUCTION

In preparation for the launch of hyperspectral imagers/sounders in geosynchronous orbit over the next decade, the Cooperative Institute for Meteorological Satellite Studies (CIMSS) is emphasizing research and development activities using simulated data sets, and aircraft high-spectral-resolution data sets from the Scanning-HIS (S-HIS) and the NAST-I (NPOESS Airborne Sounder Testbed-Interferometer). The aircraft measurements along with radiative transfer calculations allow the construction of simulated data sets to support these activities. The simulated data sets are based on the GIFTS (Geosynchronous Imaging Fourier Transform Spectrometer) instrument (Smith et al. 2000).

The GIFTS data processing algorithms are built upon CIMSS's 20 years of experience working with high-spectral resolution measurements. The primary retrieval algorithms for GIFTS are 1) temperature and moisture, and 2) motion vectors, or winds. Currently, only the clear-sky radiances are utilized by the temperature/moisture retrieval algorithm. Whereas contemporary satellite-derived motion vector algorithms utilize single channel radiance images to identify individual elements to track and calculate displacements (Velden et al. 1997, 1998), the GIFTS winds system uses the retrieved moisture fields on constant altitude surfaces to identify gradients for motion vector calculation. This represents a novel approach to wind tracking, since it eliminates the vector height assignment issue (often the largest source of error).

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2. BACKGROUND

The contemporary algorithm utilized to derive winds from GOES at NESDIS has been evolving since 1980 (Nieman et al. 1997), and now provides routine wind products for national and international users. This algorithm is fully automated and includes an elaborate quality control step as part of post-processing. CIMSS has played a major role in the development and advancement of this winds algorithm, which uses the approach of tracking features in clouds and water vapor gradients from selected channels on geostationary satellites. The current/traditional method employs sequential images of clouds and moisture derived from radiance fields to track the motion of selected targets (e.g., well-defined clouds, moisture gradients). This method has proven successful and effective in deriving wind fields, and numerous studies have indicated the usefulness of the satellite-derived wind data on weather analysis and forecasting (Velden et al. 1997, 1998).

Although the satellite derived cloud and water vapor radiance-tracked winds have been shown to improve numerical weather prediction forecasts on both regional and global scales (Soden et al. 2002; Goerss et al. 1998), a deficiency exists in the ambiguity of the vector height assignment. The current methods to assign an altitude to a derived vector rely on a combination of radiance information, semi-transparent cloud corrections, and an NWP model forecast temperature profile. Often, accurate wind tracers are assigned to the wrong altitude causing difficulties in assimilating the GOES winds (Nieman et al. 1993). Assumptions are made that the target motion represents a single level, and methods have been derived to best approximate this level. However, in reality, the targets are three-dimensional and represent a moving volume. Therefore, the vector height assignments represent the greatest source of error in estimating tropospheric motions from geosynchronous satellites.

2. APPROACH

The hyperspectral data will foster in a new approach for retrieving winds from geosynchronous satellites. The current GOES application only provides clear sky upper-tropospheric winds from images of three water vapor channels. The GIFTS measurement concept for altitude resolved "water vapor winds" from hyperspectral measurements should provide the needed vertical resolution to provide profiles of wind velocity necessary to realize the full potential of satellite measurements toward improving weather forecasts. As part of the NASA/NOAA GIFTS assessment program, CIMSS has been tasked to demonstrate the concept of this new approach to passive wind tracing. This concept can be tested using existing data.

Specifically, an algorithm to derive clear-sky, altitude-resolved water vapor winds is being developed and evaluated using simulated GIFTS data. The method utilizes the same basic automated tracking code developed at CIMSS, however the input to the algorithm is in the form of constant-level moisture analyses derived from hyperspectral sounding information. In clear-sky regions, vertical profiles of moisture can be derived from the simulated multiple GIFTS water vapor sensing channels (it has already been extensively demonstrated through GIFTS aircraft experiments how well these moisture features can be depicted). Data cubes are processed and merged into 3-dimensional analyses of moisture variables (such as mixing ratio). In this approach, sequences of retrieved water vapor fields (such as constant-pressure mixing ratio analyses) become the ‘imagery’ for tracking winds. Since the moisture fields will already be analyzed to constant pressure surfaces by the retrieval, the heights of tracked moisture gradients (water-vapor wind vectors) will be pre-determined. The height assignment error that contemporary GOES winds suffer should be minimized, and improved water vapor tracked winds should result. Furthermore, the hyperspectral information allows analyses of moisture at multiple vertical levels, which can then be used to attempt winds tracking to create vertical profiles of wind.

To date, the new scheme has been trialed on simulated data from GIFTS, and on one case of real data from airborne observations provided by the NAST-I instrument. From these first attempts, the "proof of concept" is successfully illustrated, and preliminary results are shown below.

3. RESULTS

GIFTS data were simulated using the GIFTS forward model retrievals and mixing ratio (Q) fields from MM5 model output on 12 June 2002 over the southern Great Plains. While generally clear sky conditions were prevalent prior to convective initiation, a cloud mask was added to eliminate data below the level of any detectable cloud tops in all of the Q fields (therefore, no vectors are attempted beneath clouds). Three time steps at 30-minute intervals were used to track Q gradients on pressure-resolved horizontal planes at 50mb increments from 1000-350mb. A visualization of the resultant wind fields is given in Figure 1.

The tracking results for 500mb are shown in Figure 2. Resultant winds are shown for three experiments designed to illustrate the upper and lower bounds that might be expected given “perfect” retrieval conditions, versus retrievals performed with noise introduced into the simulated radiance fields. The winds derived straight from the MM5 fields (no GIFTS information) are also shown for comparison.

As can be seen in Fig. 2, the concept of tracking moisture analysis fields is achievable. As expected, the introduction of simulated GIFTS information into the analyses degrades the vector output from the “perfect” (model-only) scenario, but not significantly, unless amplified noise is introduced. The resultant wind field coverage (with expected noise) is a significant improvement over what is currently achievable from geosynchronous satellites, especially given the profile-nature of the wind information.

In a first attempt to assess the vector quality that should be achievable from this new approach, we examined winds derived from hyperspectral observations taken from the airborne NASTI instrument flown during a mission that gathered observations off the coast of California on 11 Feb 2003. The flight tracks and coverage are shown in Figure 3. A Doppler Wind Lidar (DWL) was also flown, and was used to help validate the accuracy of the NASTI winds.

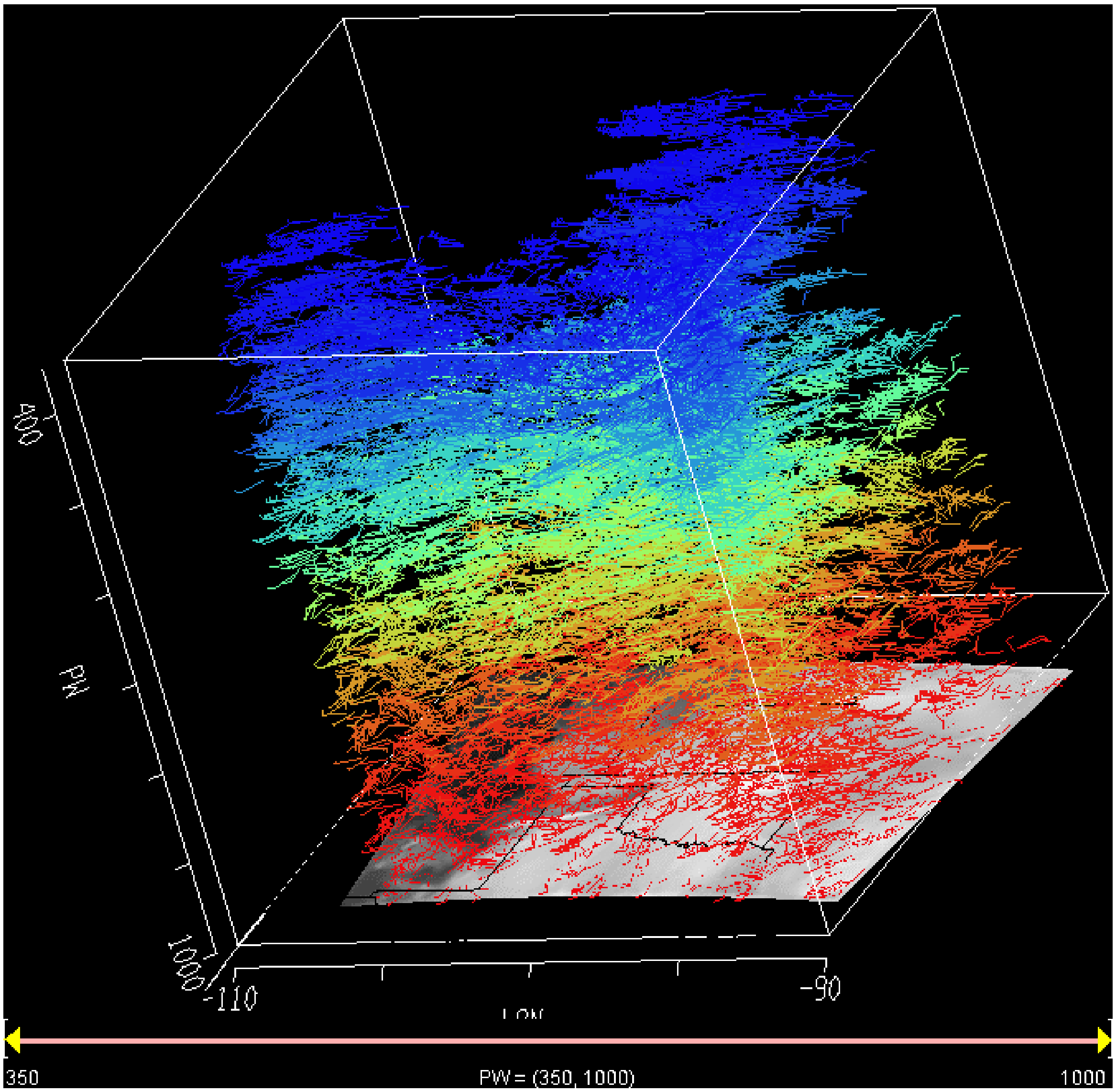

Figure 1. VisAD display of the simulated GIFTS winds illustrates the data density and vertical distribution.

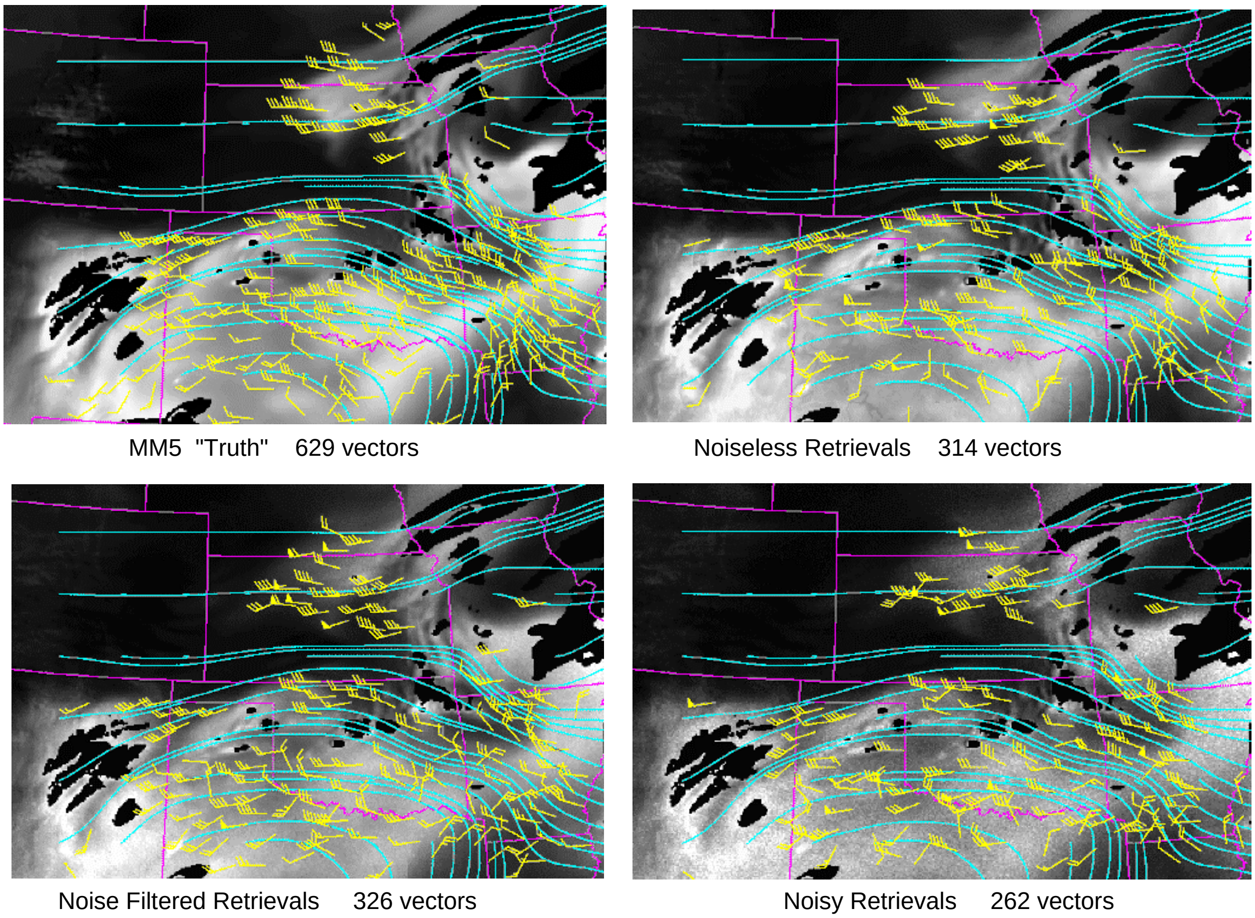

Figure 2. Plots of the wind vectors derived from tracking 3 sequential 500mb moisture analyses derived from: MM5 Q field only (upper/left), MM5 with simulated GIFTS and no introduced noise (upper/right), MM5 with simulated GIFTS and “expected” (specification-level) noise (lower/left), and MM5 with simulated GIFTS and amplified noise (lower/right).

Utilizing the approach and methodology discussed above, wind fields were derived from the NASTI moisture analyses. Since there were nine successive overpasses of the same domain, 3 sets of winds (each using 3 sequential analyses centered at 21, 22 and 23 GMT) were attempted. Examples of the resulting wind fields are shown in Figure 4 for several selected pressure levels. As can be seen, even though the domain is spatially limited by the overflight scan angles, coherent vectors are produced.

In order to validate the quality of the winds shown in Fig. 4, wind profiles from the coincident DWL observations were used as a comparison. Figure 5 shows one such comparison. The profiles match nicely, with deviations in wind speed limited to less than 3 m/sec.

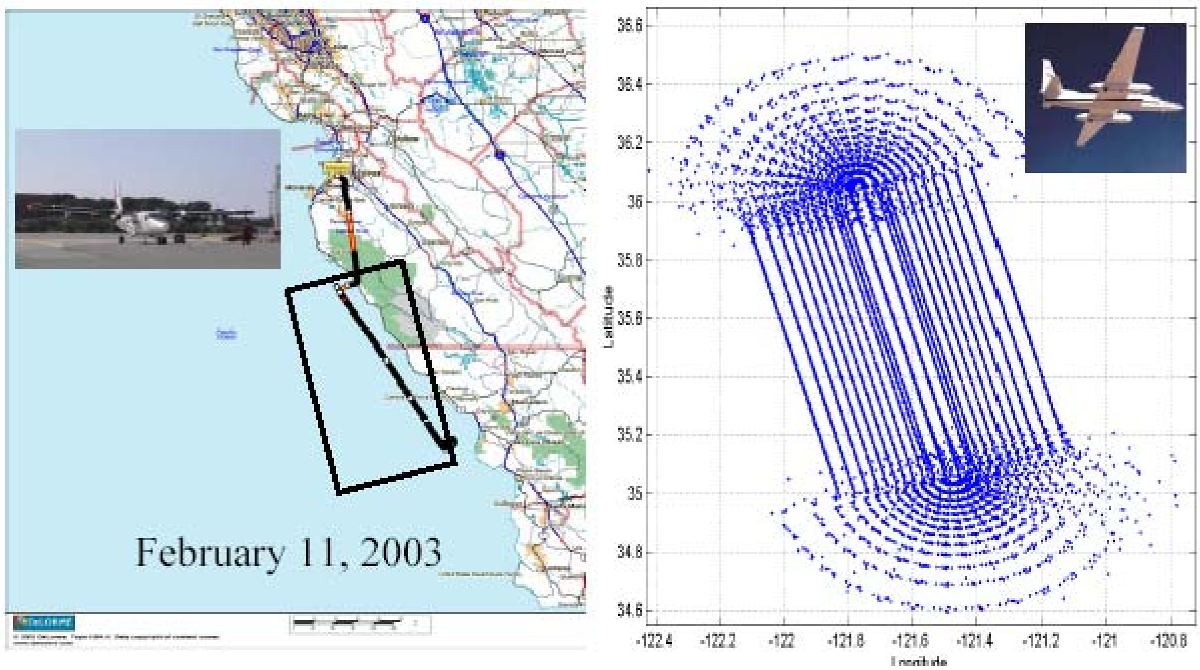

Figure 3. A racetrack aircraft flight pattern was flown over the region shown above. This provided multiple overpasses of the same region, and allowed sequential moisture fields to be derived for winds production.

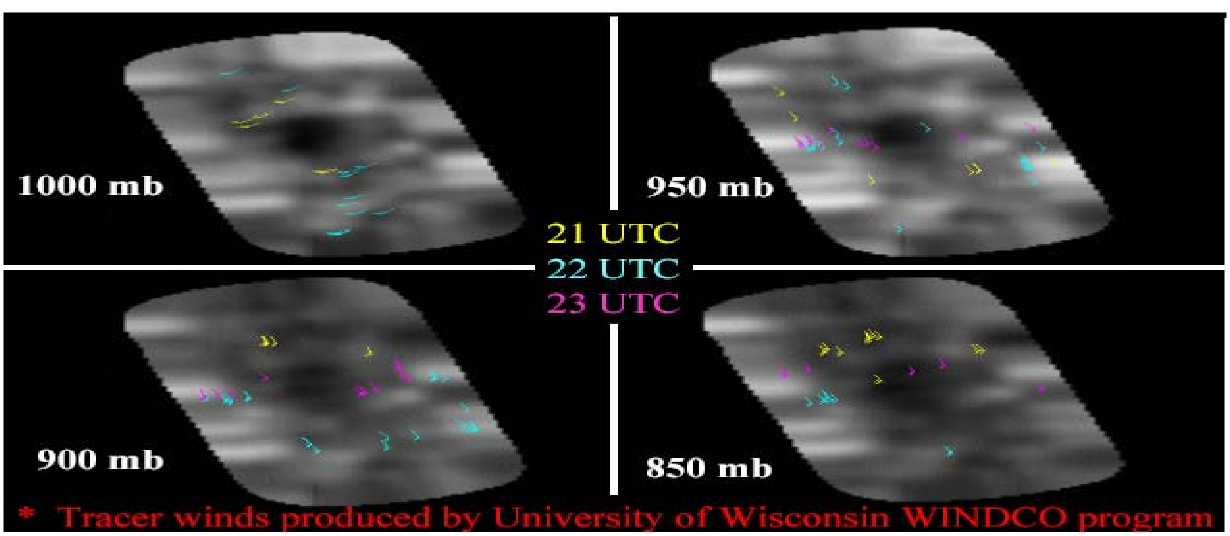

Figure 4. Tracer winds produced by CIMSS algorithms from NASTI moisture analyses.

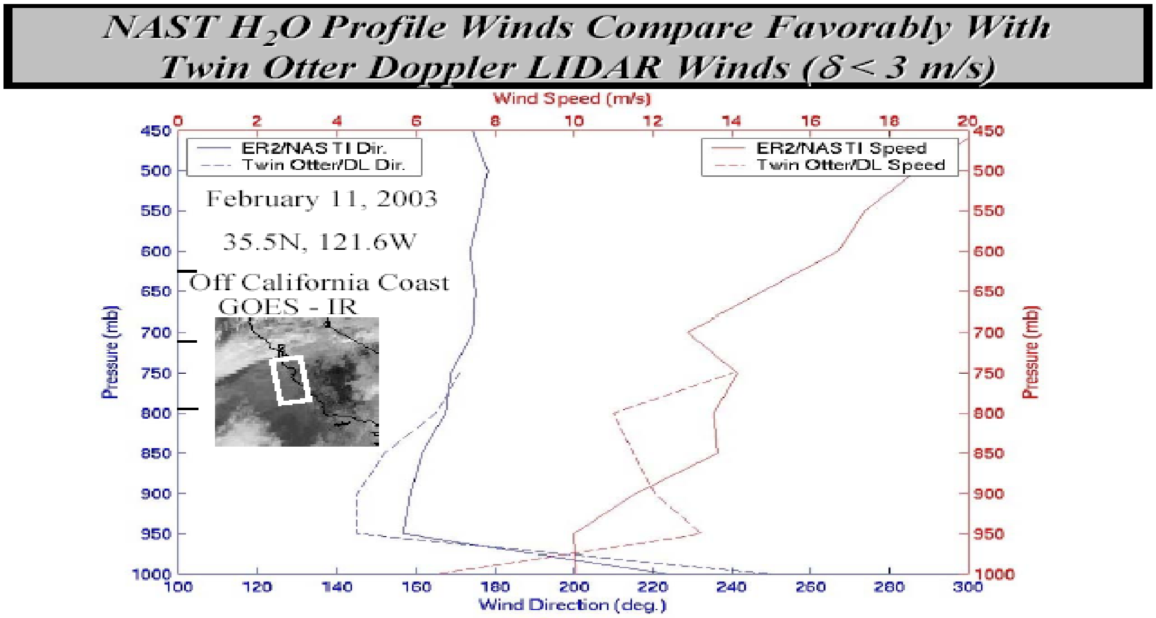

Figure 5. Wind vectors derived from the NASTI fields are compared to coincident wind LIDAR measurements and show good qualitative agreement.

4. SUMMARY

CIMSS is developing the aforementioned new approaches to passive wind tracing that will be possible from hyperspectral sounders to be flown on future geosynchronous satellites. These new concepts have been demonstrated by first examining simulated hyperspectral data sets, and also on one case of real data from airborne observations provided by the NAST-I instrument. The results from the NASTI case show good agreement with a doppler wind lidar also flown on the aircraft. This new methodology to retrieve winds from satellites in cloud-free areas could become a new standard in regions where geosynchronous satellite hyperspectral observations are available.

5. REFERENCES

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