REVIEW OF OBSERVING SYSTEM SIMULATION EXPERIMENTS TO EVALUATE THE POTENTIAL IMPACT OF LIDAR WINDS ON WEATHER PREDICTION

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1. INTRODUCTION

Observing System Simulation Experiments (OSSEs) are an important tool for evaluating the potential impact of proposed new observing systems, as well as for evaluating trade-offs in observing system design, and in developing and assessing improved methodology for assimilating new observations. Extensive OSSEs have been conducted at NASA/ GSFC and NOAA/AOML in collaboration with Simpson Weather Associates and operational data assimilation centers over the last 25 years. These OSSEs determined correctly the quantitative potential for several proposed satellite observing systems to improve weather analysis and prediction prior to their launch, evaluated trade-offs in orbits, coverage and accuracy for space-based wind lidars, and were used in the development of the methodology that led to the first beneficial impacts of satellite surface winds on numerical weather prediction. In this paper, we summarize OSSE methodology and present results from OSSEs to evaluate the potential impact of space-based lidar winds on numerical weather prediction (NWP).

2. METHODOLOGY

The methodology currently used for OSSEs consists of the following elements: (1) A long atmospheric model integration using a very high resolution "state of the art" numerical model to provide a complete record of the assumed "true" state of the atmosphere referred to as the "nature run". (2) Simulated conventional and space-based observations from the nature run. (3) Control and Experimental data assimilation cycles. (4) Forecasts produced from the Control and Experimental assimilations. The analyses and forecasts are then verified against the nature run to obtain a quantitative estimate of the impact of proposed observing systems and the expected accuracies of the analysis and forecast products that incorporate the new data. In a "QuickOSSE", one or more very accurate numerical model forecasts of five to ten day duration may be used as a mini-nature run. Observations are then simulated and data assimilation experiments are performed in a manner similar to that described above. The advantage of the QuickOSSE approach is that the impact of a proposed observing system can be evaluated with regard to a specific storm. In addition, the cost of a QuickOSSE is much lower and the results are obtained more rapidly. Nevertheless, QuickOSSEs cannot yield the statistical significance that might be required, and should only be used as an adjunct to the complete OSSE methodology.

3. RECENT OSSE TO ASSESS THE POTENTIAL IMPACT OF LIDAR WINDS

A series of OSSEs are being conducted in order to determine the potential impact of space-based lidar wind profiles on NWP and to evaluate tradeoffs in lidar instrument design. In the first of these experiments, the nature run was generated using the Finite Volume General Circulation Model (FVGCM), and the assimilation and forecast system was the operational version of the GEOS Data Assimilation System. Following a very detailed assessment of the realism of the nature run and the differences between the nature run model and the assimilation/ forecasting model, the entire OSSE system was validated through a comparison of parallel real data and simulated data impact experiments. Then parallel assimilation experiments and five-day forecasts were performed with this system to evaluate the impact of space-based lidar wind profiles. As in earlier OSSEs, one of the major metrics for assessing the potential impact of lidar winds was the anomaly correlation for sea level pressure and 500 hPa height forecasts. In addition, a number of additional metrics, such as impact on the central pressure and displacement of cyclones or the landfall of hurricanes were also evaluated.

The results of this evaluation agreed with earlier OSSEs, summarized in Atlas, 1997 [1] and showed a very substantial improvement in forecast accuracy resulting from the assimilation of space-based 1idar winds. In the Southern Hemisphere, average forecast skill was extended by 12-18 hours, while in the Northern Hemisphere, average forecast skill was extended by 3-6 hours. This was associated with a meaningful (10%) reduction in position error for all cyclones averaged over the globe and all time periods. For very intense cyclones (those with central pressure less than 945 hPa), the reduction of position error exceeded 200 km. Figure 1 shows the potential impact of lidar wind profiles on forecast accuracy in the Northern Hemisphere, while figure 2 illustrates an improvement in hurricane landfall prediction as a result of assimilating lidar data. This result was obtained for the first hurricane in the nature run. The predicted landfall position error for this and another tropical cyclone to hit the U.S. mainland in the nature run was improved by approximately 150 miles for both storms. These results demonstrate considerable potential for space-based lidar wind profile measurements, however further experiments are required to evaluate the specific advantages and disadvantages of alternative technologies and orbits for proposed lidars.

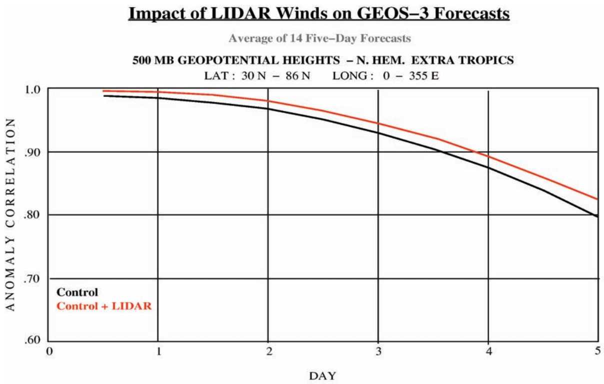

Figure 1. Potential impact of lidar wind profiles on NWP.

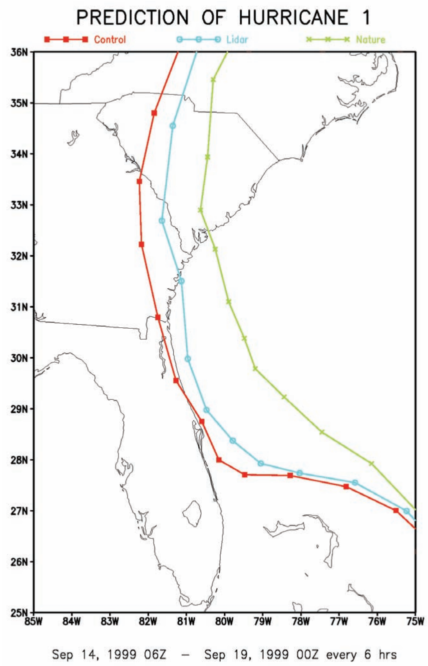

Figure 2 Illustration of the potential impact of lidar winds. Green: actual track from nature run. Red: forecast beginning 63 hours before landfall with all currently used data. Blue: improved forecast for same time period with simulated wind lidar added.

4. RESULTS FROM A QUICKOSSE FOR HURRICANE IVAN

The results presented in figure 2 are for a hypothetical hurricane within the three and one half month nature run, described earlier. The 2004 and 2005 hurricane seasons were extremely active with several major hurricanes striking the United States. The QuickOSSE methodology was conceived in order to answer observational and dynamical questions related to these specific hurricanes. Here we present results from one such QuickOSSE for Hurricane Ivan to address the potential impact of space-based wind profile observations, as well as to better understand the role of the area averaged divergence profile in the movement of this storm. A .25 degree resolution fvGCM forecast of hurricane Ivan was used as the nature run for this experiment. From this nature, all of the standard and special reconnaissance observations, that were available in rcal - time, as well as hypothetical lidar wind profiles covering the storm, were simulated. This was followed by a Control assimilation and forecast (using all of the standard observations) and an ideal lidar assimilation and forecast (adding simulated lidar winds to the control) generated using a coarse 1.0 by 1.25 degree resolution version of the model. Figure 3 shows a major improvement in the predicted direction of movement of the hurricane resulting from the assimilation of lidar winds. This was due to a significant improvement in the divergence profile associated with the storm (not shown), that enabled it to be more accurately steered by the large-scale flow.

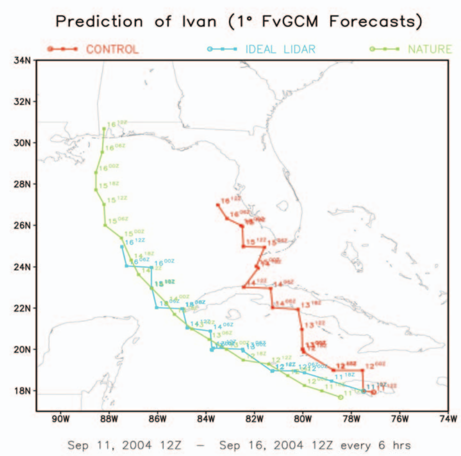

Figure 3 Tracks of hurricane Ivan from Nature Run, Control forecast, and forecast with lidar winds added.

5. CONCLUSIONS

All of the OSSEs that we have conducted from 1985-2006 have demonstrated tremendous potential for lidar wind profile data to improve atmospheric analyses and forecasts. This has been true for differing data assimilation systems, analysis methodology, and model resolutions. OSSEs have shown the impact of wind profile data to be only very slightly dependent on the magnitude of the random (uncorrelated) errors of the observations. OSSEs also clearly show much greater potential for observations of the complete wind profile than for single-level wind data or observations of the boundary layer alone. A new methodology, referred to as QuickOSSE, also shows significant potential for lidar winds to improve hurricane prediction. OSSE's continue to be conducted as a joint project to determine the quantitative impact of space-based lidar wind observations in current and future operational and research data assimilation systems, the precise requirements for accuracy, coverage and resolution, the relative impact of proposed instruments. Some preliminary results from these most recent OSSEs will also be discussed at the meeting.

REFERENCE:

[1] Atlas, R., 1997: Atmospheric observations and experiments to assess their usefulness in data assimilation.. J. Meteor. Soc. of Japan, 75, 111-130.