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Evaluating Space Based Doppler Wind Lidar using a full OSSE at NCEP

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1. Introduction

The forecast skill evaluations performed using simulation experiments are known as Observing System Simulation Experiments (OSSEs). Among the many future instruments the Doppler Wind Lidar (DWL) has often been evaluated by OSSEs ([1], [4], [5], [10]) because it is a very costly instrument and, therefore, justifies the cost of an OSSE. In this paper, results are presented from DWL-OSSEs which were conducted at NCEP in collaboration with the National Environmental Satellite Data and Information Service (NESDIS), Simpson Weather Associates (SWA), and the National Aeronautics and Space Administration (NASA).

Throughout the simulation experiments, realistic data should be processed. NCEP's OSSE is the first where satellite level-1B radiance data [7] were simulated and assimilated. In some OSSEs satellite radiance data are simulated as retrieved temperature profiles. Sometimes retrieved temperature is simulated by simple interpolation. Without radiance data, a large impact from DWL over the Southern Hemisphere is obtained but does not represent the real world impact. DWL is often simulated as a vector wind, but in the NCEP OSSE it is simulated and assimilated as line of sight wind (LOS). The details of the NCEP OSSE are described in [7] and [11].

2. The NCEP elements of the OSSEs

The NR, which serves as a proxy for the true atmosphere in OSSEs, needs to be sufficiently representative of the real atmosphere yet different from the model used for the DAS. The observational data for existing instruments are simulated from the NR, and forecast and analysis skill for the real and simulated data are compared. For this project the NR was provided by ECMWF. The description and evaluation of the NR used for the NCEP OSSE are provided by [2]. The one-month-long forecast run was made at a resolution with a triangular truncation of 213 (T213) and with 31 vertical levels starting on 5 February 1993.

The NCEP global DAS is based on the Spectral Statistical Interpolation (SSI) of [8] and [3]. The March 1999 and 2004 versions of NCEP's operational Medium Range Forecast model and DA system were used for the data impact tests presented in this paper. A spectral triangular truncation at 62 (T62) model was used for most of the experiments and the effect of model resolution is discussed, using a T170 model for comparison.

3. Simulation of Doppler Wind Lidar (DWL)

In the NCEP OSSE, instead of evaluating a specific instrument four representative types of DWL are evaluated:

- scan_DWL: DWL with scanning, sampling from all vertical levels;
- non_scan_DWL: DWL without scanning, sampling from all vertical levels and in only one direction;
- scan_DWL_Upper: DWL with scanning, sampling from upper levels;
- scan_DWL_Lower: DWL with scanning, sampling from lower levels and clouds.

Upper and lower level sampling represent DWL measurements of molecular, aerosol and particle returns, respectively. The non_scan_DWL is similar to DWL for ADM mission (Stoffelen et al. 2005). Through these experiments we expect the data impact from each specific type of DWL can be estimated from the data impact of these four DWLs. Wind data from the DWLs were simulated as LOS components of wind, which is the component along a direct line between a satellite and an observation point. Assimilation code for LOS wind was implemented into the NCEP DAS

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and has been tested through the OSSEs.

4. Evaluation of basic DWL data

The improvement in AC forecast skill for the wind fields is about 1% with the scan_DWL. The data impact shown at the total scale is mainly from planetary scale waves. It was expected that the main impact of DWL would be at smaller scales [10], and Fig. 1 confirms that the impact is much larger at the synoptic scale. The improvement in AC is nearly up to 3%.

Since scanning allows the measurement of divergent wind, which cannot be estimated from mass fields, this advantage was expected. However, the results could be due just to the amount of data in the experiments, since the number of measurements of the scan_DWL is almost 20 times more than the non_scan_DWL. In Fig. 1, AC from 20 thinned scan_DWL measurements is also included to demonstrate that scanning is indeed important. It is interesting to observe that thinned data could be better than the full data in an 850hPa synoptic scale analysis. Although the results clearly show the advantage of scanning, an overwhelming technical difficulty in scanning has been reported. Based on the results form the NCEP OSSE, a multiple satellite system with non-scanning lidars or one satellite with at least four different directional lidar beams have been considered.

5. Data impact and DAS

When scan_DWL is included, the improvement in the analysis is similar to the 1999 DAS and 2004 DAS, and the apparent impact from the CTL may be reduced in the 2004 DAS (Fig. 2). However, the forecast of CTL is much better with the 2004 DAS than with the 1999 DAS. Skill with scan_DWL using the 2004 DAS is much better than the 1999 DAS skill. These results show the apparent data impact could be reduced when a better DAS is used.

6. Data impact and model resolution

In the previous section, DWL was evaluated using a T62 model. However, the results using a higher resolution model could be different. The data impact with better models may be reduced because they can provide much better background fields, leaving less "room" to improve the analysis. On the other hand, a higher resolution model should be able to utilize the data in finer detail which may lead to more data impact.

Data impacts of scan_DWL with respect to the CTL are reduced in the T170 model. This is because the forecast fields from the T170 model are already good, which leaves less room for improvement. These results can be interpreted to mean that if the model is poor it easily produces a large analysis impact due to poor guess fields, but the large analysis impact rapidly decreases with forecast time. If the model is sufficiently good, the small analysis impacts will grow with forecast time.

The impact of increasing the model resolution to T170 is comparable to adding the best_DWL at the total atmospheric scale. However, at synoptic scales the impact of DWL exceeds that seen from the improvement due to T170 resolution (Fig. 3). The model improvement seems to be more important in improving the forecast of planetary scale waves. However, any improvement in the forecasts of synoptic scale waves requires better data to become more important.

7. Combined impact

The combined impact of DWL-NonScan with DWL-Lower is also evaluated in Fig 4. Improvement in AC from experiments without lidar are presented. At 200hPa there are almost no observations by DWL-lower but there is a significant number of observations by the DWL-NonScan, but with the scanning DWL-Lower showing more impact than DWL-NonScan. Combining the DWL-NonScan and DWL-Lower will increase the AC by 0.3% in the analysis and nearly 0.8% in the two day forecast.

8. Summary and discussion

From the experience of the OSSEs performed during recent decades, we realize that using the same NR is essential in conducting OSSEs to deliver reliable results in a timely manner. The simulation of observations requires access to the complete model level data and a large amount of resources, and it is important that the simulated data from many institutes be shared between all the OSSEs. By sharing the NR and simulated data, OSSEs will be able to produce results that can be compared, which will enhance the credibility of the results. Based on these experiences a broad group of US and international partners formed the "Joint OSSEs" [6].

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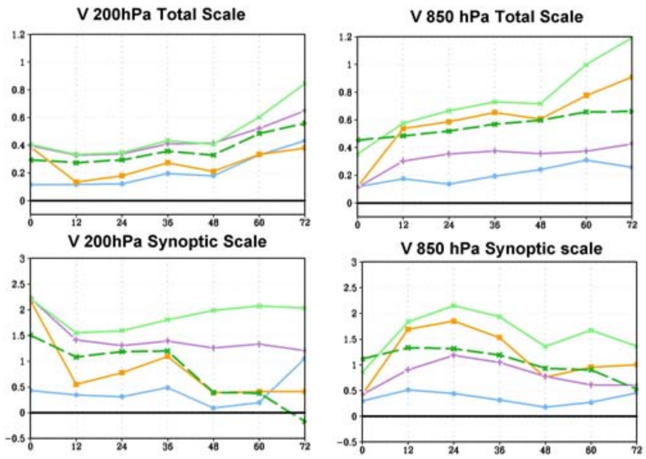

Fig. 1
Time-averaged anomaly correlations between the forecast and NR for meridional wind (V) fields at 200hPa (top) and 850 hPa(bottom), for the NH. Left two panels are for the total scale and right two panels for the synoptic scale. The differences from AC for the CTL are presented. In these experiments the CTL assimilates conventional data and TOVS radiance data.

Green with x: scan_DWL+CTL data
Purple with closed circle: scan_DWL_upper+CTL data
Orange with square : scan_DWL_lower+CTL data,
Blue with ciccle: non_scan_DWL+CTL data.
Dashed green line: scan_DWL with 20 time thinned measurements

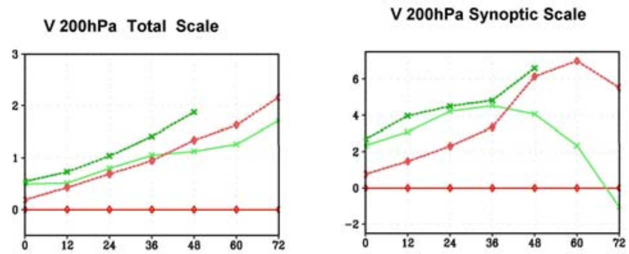

Fig. 3 This diagram shows a comparison between the improvement from additional data and the improvement from increased model resolution.

Solid red line with diamond: CTL for T62 model
Dotted red line with diamond: CTL for T170model
Solid green line with x: with scan-DWL+CTL and T62 model
Dotted green line with x: with scan-DWL+CTL and T170model

Differences in AC with a NR from the control (CTL) for 200hPa meridional wind in the NH is presented. The left panel is for ACs computed using the total scale; the right panel shows ACs for the synoptic scale. In these experiments the CTL assimilates only with conventional data.

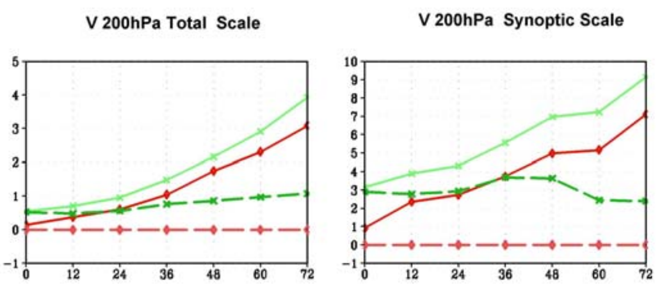

Fig. 2 This diagram shows a comparison between the improvement from additional data and the improvement from a new DAS.

Dashed red line with diamond: CTL for 1999 DAS
Solid red line with diamond: CTL for 2004 DAS
Dashed green line with x: with scan-DWL+CTL and 1999 DAS
Solid green line with x: with scan-DWL+CTL and 2004 DAS

Differences in AC with a NR from (CTL) for 200hPa meridional wind in the NH is presented. The left panel is for ACs computed using the total scale; the right panel shows ACs for the synoptic scale. In these experiments the CTL assimilates conventional data and TOVS radiance data.

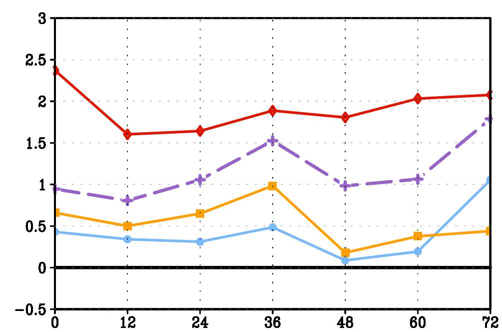

Fig. 4 Synoptic scale 200hPa V anomaly correlation. The difference from control experiment are plotted. The control is the experiment with no DWL. All experiments include conventional data and TOVS radiance data.
Red Diamond: 100% scan_DWL_Lower+ 100% scan_DWL_upper
Dashed purple with +: scan_DWL_Lower+ non_scan_DWL
Orange square scan_DWL_Lower only
Blue circle: non Scan DWL only
Difference from CTL with conventional data and NOAA11 and NOAA12 TOVS data