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Observing System Simulation Experiments for NPOESS

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1. INTRODUCTION

The future National POES System (NPOESS) is scheduled to fly during the 2007-2010 period. For the next 10 years, a considerable amount of effort must take place to define, develop and build the suite of instruments which will comprise the NPOESS. The forecast impact of current instruments can be assessed by Observing System Experiments (OSEs), in which already existing observations are denied or added to observations from a standard data base. However, the impact of future instruments must be assessed with experiments using simulated observations. These experiments are known as Observing System Simulation Experiments (OSSEs).

This project is a collaboration among several organizations. Data assimilation will be performed mainly by a technology-neutral organization, the National Centers for Environmental Prediction (NCEP), and repeated by NASA/Data Assimilation Office (DAO). From the instrument community, Simpson Weather Associates (SWA) and NOAA scientists are participating in the simulation of Doppler Wind Lidar (DWL) observations, and the National Environmental Satellite, Data and Information Service (NESDIS) will simulate both existing and future thermodynamic sounders. NASA/DAO will simulate conventional observations as well as ACARS and cloud track winds.

Through this collaboration, the data assimilation and modeling communities can be involved in instrument design and can provide information about the expected impact of new instruments. Furthermore, through the OSSEs, operational data assimilation systems will be ready to handle new data in time for launch of new satellites. This process involves preparation for future data volumes in operations, the development of the data base and data-processing(including formatting) and a quality control system. All of this development will accelerate the operational use of data from the future instruments (Lord et al. 1997).

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For the OSSE, a long integration of an atmospheric general circulation model (GCM) is required to provide a "true atmosphere" for the experiment. This is called the "nature run". The nature run needs to be sufficiently representative of the actual atmosphere and but different from the model used for the data assimilation. Obtaining the nature run and its evaluation is the first step of the OSSE process (Masutani et al. 1999, Lord, et al. 2001). The observational data for existing instruments is simulated from the nature run and impact tests are performed for both real and simulated data. Calibration of the OSSEs are conducted by comparing the simulated and real impact tests. Then OSSEs for future instruments can then be performed with a calibrated system and relative impacts on forecast systems estimated.

2. THE NATURE RUN

For this project, the nature run was provided by the European Centre for Medium-Range Weather Forecasts (ECMWF). A one month model run was made at resolution T213 and 31 levels starting from 5 February 1993. The version of the model used for the nature run is the same as for the ECMWF reanalysis, containing Tiedtke's mass flux convection scheme (Tiedtke 1989) and prognostic cloud scheme (Tiedtke 1993).

The nature run was found to be representative of the real atmosphere in many ways (Masutani et al. 1999a,1999b). The cloudiness, however, was biased low for marine stratocumulus and high over Northern Hemisphere (winter) continents and required a statistical correction to provide reasonable sampling of simulated observations (Masutani, et al. 1999b, 1999c). Another nature run has been prepared by NASA/DAO covering a summer period when hurricanes were observed.

3. SIMULATION OF OBSERVED DATA

The initial simulation experiment uses a subset of the same real observational data distribution available in February 1993 including ACARS and cloud track satellite winds. Cloud track winds based on the nature run wind will also be tested. HIRS and MSU from NOAA 11 and NOAA 12 are simulated but HIRS from NOAA-12 was not used for calibration because it was not used operationally in February 1993.

For future instruments, space based DWL winds are simulated by SWA. The algorithm and strategies for simulation of AIRS have been developed and are ready to be simulated by NOAA/NESDIS soon.

3.1 *Simulation of Conventional Observations*

The simulation of realistic conventional observations and satellite observations, consisting of cloud motion wind vectors is being conducted by Atlas and Terry (2000). Information from the February 1993 observational database is used to obtain the necessary spatial and temporal distribution to produce a representative sampling for the simulated observational database

Uncorrelated random noise is added to perfect simulated observations using a Gaussian normal distribution of numbers scaled by the observational error standard deviations. A The observational error standard deviations (Stoffelen et al., 1994) are obtained from tables produced at ECMWF for each observing system, mandatory pressure level and atmospheric quantity that is directly measured. For rawinsondes, an additional error of 10% is applied to significant level observations. In addition to random noise a large scale correlated error is added and its effects are being evaluated.

Due to the improved accuracy of observations from ACARS over those obtained from conventional aircraft, conventional aircraft observation errors would be too pessimistic if applied to ACARS. Instead, rawinsonde errors are used since rawinsondes appear to resemble ACARS more closely than any other observing system with respect to the magnitude of the observational error (Schwartz and Benjamin,1995).

3.2 *Simulation of Tovs Radiance Data*

HIRS and MSU from NOAA 11 and NOAA 12 are simulated by NOAA/NESDIS (Lord et al., 2001). The basic radiative transfer code is RTTOV version 5 (Saunders et al., 1998). This code can produce both clear and cloudy radiances, and permits user -specified emissivities. This code is used because it has a different design philosophy and uses different spectroscopy than the one used in the operational NCEP global data assimilation system,, which is based upon OPTRAN (McMillin et al., 1995). This is important to avoid over- optimistic results in the OSSEs due to the so-called the "identical twin" problem.

Instrument noise was characterized by collecting statistics from space calibration data for one day in the middle of the nature run. Correlated Gaussian noise was generated by the method of Searle (1988), and added to the computed radiances. Finally the radiances were converted to instrument counts using the TOVS level-1b radiance (T1B) calibration coefficients that correspond to that scan line. T h e methodology for simulating MSU observations is identical to that of the HIRS, with the exception of surface emissivity. Here the microwave surface emissivity model that is included with RTTOV is used (English and Hewison, 1998).

3.3 *DWL Data Simulation*

The first simulated DWL wind data are produced as line-of-sight (LOS) winds by SWA using their Lidar Simulation Model (LSM). LOS winds and meta data have been formatted into WMO standard BUFR. The simulation of DWL data involves generic DWL performance models, atmospheric circulation models and atmospheric optical models (Atlas and Emmitt, 1995; Emmitt, 1995a; Emmitt and Wood,1996). The instrument parameters are provided by the engineering community. Scanning and sampling requirements are provided by the science community and define various instrument scenarios.

Bracketing sensitivity esperiments are being performed for various DWL concepts to bound the potential impact (Lord et.al 2001). Scanning, and various data sampling strategies are being tested with these experiments. No measurement error is assigned for these initial tests but will be added in the future. Strategies for systematic errors are discussed by Emmitt (2000).

4. DATA ASSIMILATION SYSTEM

The data assimilation system at NCEP is based on the "Spectral Statistical Interpolation (SSI)" of Parrish and Derber (1992), which is a three-dimensional variational analysis (3-D var.) scheme. In 1995, the assimilation system was modified to use TOVS cloud-cleared radiances instead of temperature and moisture vertical retrievals, and significant improvements were reported by Derber and Wu (1998). In January 1998, the use of raw radiance data (traditionally referred to as level-1b data) became operational (McNally et al., 1998, 2000) and an upgrade to this system was implemented in June 1998. The March 1999 version of NCEP's operational Medium Range Forecast (MRF) and data assimilation system is used for the current data impact test. LOS winds from DWL are directly used in the data assimilation.

5. CALIBRATION FOR OSSE

Calibrations for OSSEs are performed for existing instruments (Lord 2001a, Lord 2001b). Denial of RAOB wind, RAOB temperature, and T1B with various combinations are tested. The analysis with all conventional data and T1B is used as control (CTL) and root mean square error (RMSE) from CTL are shown in Fig.1. The results show generally satisfactory agreements between real and simulated impact.

The impact of RAOB winds (R_Wind) is slightly weaker in simulation (Fig.1a, d) and the impact of RAOB temperature (R-Temp) is slightly stronger in the simulation (Fig. 1 b,e). In the tropics, simulations show a large impact of R_Temp in the low troposphere, but that magnitude does not increase with forecast time and by the 72 hour forecast time the difference between the experiments with CTL and experiments without R_Temp (1bNTMP) is similar to the difference between CTL and experiments without R_Wind (1BNWIN). The large analysis impact is related to the bias between the NCEP model and the nature run. Including a bias correction in the data assimilation is being considered (Purser and Derber, 2001).

Impact of T1B is slightly larger in simulation (Fig. 1 c,f). In the northern hemisphere (NH), T1B has little impact over Europe and Asia but shows impact over the Pacific for both real and simulated analysis. The magnitudes are slightly larger in simulation but patterns are similar. In the 72 hour forecast the impact of T1B spreads out over the NH and shows a similar magnitude of impact compared to R_Temp. In the southern hemisphere (SH), T1B dominates. However, with T1B, RAOB data do exhibit some impact and their impacts are similar between simulated and real analysis.

One of the reasons for the larger impact of T1B in simulation is the lack of measurement error in the simulated data. Under-estimation of the cloud effect in the simulation is another possible reason for the large impact in simulation.

6. SOME INITIAL RESULTS FROM THE OSSE FOR DWL WINDS

Among many candidate instruments for the OSSE, DWL winds are simulated by SWA. According to the strategy for bracketing sensitivity experiments (Lord 2001a, Lord 2001b), scanning or non-scanning, various wave length, number of LOS per measurement, are being tested. Sensitivity to weight in data assimilation is also being tested.

For the first four days of assimilation, 14 combinations of DWL, TIB and conventional data were compared. Assimilation for the total one month period will be continued for selected cases. Sensitivity with respect to the CTL is considered proportional to RMSE differences between the CTL and each experiment for both wind and temperature. For 500hPa winds, in area average over the NH (20N to 80N), the sensitivity varies between negligible to 0.5 ms^{-1}. For the area average over the tropics (20S to 20S) sensitivity is 0.3 ms^{-1} to 1.3 ms^{-1}; over the SH (80S to 20S), 0.2 ms^{-1} to 1.0ms^{-1}. Sensitivity for 500hPa temperature varies from negligible to 0.1 C° over the NH; 0.1 C° to 0.3 C° in tropics; 0.1 C° to 0.5 C° over the SH. The results show major impact over tropics while Marseille et al (2001) reported major impact over the SH. The main reason is T1B radiances are included in CTL for this study and significant improvements over the SH are already achieved by using T1B.

Generally, the above results also show an advantage of a scanning instrument over a non-scanning instrument which is largest in the upper troposphere and reduced in the lower troposphere. The number of shots, an indication of observation quality, becomes more important in the lower troposphere.

It is possible to produce a large impact by just assigning large weight to the observations in the assimilation; this procedure neglects data quality, however, so that more detailed study and evaluation of forecasts is required. DWL winds also need to be evaluated with both the current data distribution and the anticipated future data distribution corresponding to when the DWL data will be used. For this reason, simulated data from at least one advanced sounder (e.g. AIRS), a scatterometer (e.g. ASCAT) and at least the current ACARS data must be added in the future. More realistically distributed, high-density, cloud drift winds need to be included.

7. FUTURE PLANS

In addition to a DWL, the atmospheric infrared sounder (AIRS), the Cross track Infrared Sounder (CrIS), Conically scanning Microwave Imager/Sounder (CMIS), and the Advanced Technology Microwave Sounder (ATMS) have been proposed as candidate instruments to be tested by OSSEs. We are proceeding to develop appropriate forward models for these instruments.

In order to make reliable recommendations the results need to be evaluated with various error assignments. Large scale spatially correlated error and systematic error in simulated data may alter the results. The results also depend on the structure of background error in the data assimilation, which defines the scale of events to be assimilated (Purser and Parrish, 2000). Since the amount of data involved in the future instruments increases drastically, effective super-observations to reduce the data set needs to be studied (Purser et al. 2001).

The OSSE will be repeated using the NASA/DAO data assimilation system. An alternative nature run from other models for the same period has also been generated to confirm the results. A seasonal dependence of the data impact is suggested. The nature runs to test northern summer time response could be important, especially to study the impact on tropical storm prediction.

The evaluation of the OSSE will include: diagnostics of strength and position of cyclone and jets and study of extreme events as well as standard forecast skill score. Cost benefit and flight planning will also be studied.

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