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Progress in Joint OSSEs

New nature runs and international collaboration

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1. INTRODUCTION

Building and maintaining observing systems (OS) with new instruments is extremely costly, particularly when satellites are involved. Objective methods that can evaluate the improvement in forecast skill due to the selection of instruments and configurations have long been sought. For future instruments, the forecast skill evaluation needs to be performed using simulation experiments, known as Observing System Simulation Experiments (OSSEs). The OSSE itself is a very expensive project; however, its cost is a small fraction of the total cost of an actual OS.

By running OSSEs, current operational data assimilation systems (DAS) can be upgraded to handle new data types and their volume, thus accelerating the use of future instruments and OS's. Additionally, OSSEs can hasten database development, and the development of data processing techniques (including formatting) and quality control software.
Recent OSSEs show that some basic tuning strategies can be developed before the actual data become available. All of this will accelerate the operational use of new OS. Through the OSSEs future OS will be designed that can be effectively used by DAS and forecast systems to improve weather forecasts, thus giving the maximum societal and economic impact ([1].[2].[3])

Among the many future instruments the Doppler Wind Lidar (DWL) has often been evaluated by OSSEs ([1].[8]) because it is a very costly instrument and, therefore, justifies the cost of an OSSE. NCEP conducted OSSEs to evaluate the impact of DWL and demonstrated that OSSEs are able to provide critical information for assessing observational data impacts [4],[9].

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2. What we can learn from OSSEs

It is a challenging task to evaluate the realism of impacts from OSSEs. Due to the uncertainties in an OSSE, the differences between the Nature Run (NR) and real atmosphere, the process of simulating data, and the estimation of observational errors all affect the results. Evaluation metrics also affect the conclusion. OSSE data impacts are often characterized as too optimistic but simulated data impacts can be pessimistic, depending on the model used. Consistency and theoretical backup of the results help in gaining confidence in the results from OSSEs. As more information is gathered, we can perform more credible OSSEs. Sometimes interpretation of the results becomes very difficult and OSSE results cannot be used to make recommendations. NCEP's OSSEs have demonstrated that carefully conducted OSSEs are able to provide useful recommendations, such as the advantages of scanning, to influence the design of future observing systems. ESA is planning multiple non-scan lidars to capture the effects of scanning and NASA has proposed the Global Wind Observing Sounder (GWOS) with multiple lidars on one satellite.

As models improve, there is less improvement in the forecast due to the observations. Sometimes the improvement in forecasts due to model improvements is much greater than the improvement due to observations. OSSEs will be able to provide guidance on where more observations are required and where the model needs to be improved.

The experience of OSSEs at NCEP also demonstrated that OSSEs often produce unexpected results. Theoretical prediction of the data impact and theoretical back up of the OSSE results are very important. On the other hand, unpredicted OSSE results will stimulate further theoretical investigation. When all efforts come together, OSSEs will help with timely and reliable recommendations for future observing systems. At the same time, OSSEs will prepare the operational DAS to promote the prompt and effective use of the new data.

3. Collaboration and coordination in OSSEs

OSSEs are very labor intensive. The NR has to be produced using a state of art NWP models at the highest resolution. Simulating data from an NR requires large computing resources. Simulations and assimilations have to be repeated with various configurations. OSSEs also require the best knowledge in many areas of the NWP system. Expert knowledge is also required for each instrument. Efficient collaborations are essential for producing timely and reliable results.

Ideally, all new instruments should be tested by OSSEs before they are selected to be built. OSSEs will also be important in influencing the design of the instruments and the configuration of the observing system. While the instruments are being built, OSSEs will help to prepare the DAS for the new instruments. We have to realize that developing a DAS to assimilate a new type of data is a significant task. However, this effort has traditionally been made only after the data become available. The OSSE effort demands that this same work be completed earlier, and that will speed up the actual use of the new data.

OSSEs will be conducted by various scientists with different interests. Some want to promote particular instruments while others may want to aid in the design of the global observing system. Specific interests may introduce bias into OSSEs but they also introduce strong motivations. Operational centers such as NCEP will perform the role of finding a balance among conflicting interests to seek an actual improvement in weather predictions. They may be unbiased but often have a difficult time finding resources.

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 which 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" [5] [6].

4. NATURE RUN

The NR is a long, uninterrupted forecast by a model whose statistical behavior matches that of the real atmosphere. The ideal NR would be a coupled atmosphere-ocean-cryosphere model with a fully interactive lower boundary. Meteorological science is approaching this ideal but has not yet reached it. For example, it is still customary to supply the lower boundary conditions (SST and ice cover) appropriate for the span of time being simulated.

The advantage of a long, free-running forecast is that the simulated atmospheric system evolves continuously in a dynamically consistent way. One can extract atmospheric states at any time. Because the real atmosphere is a chaotic system governed mainly by conditions at its lower boundary, it does not matter that NR diverges from the real atmosphere a few weeks after the simulation begins *provided that* the climatological statistics of the simulation match those of the real atmosphere. A NR should be a separate universe, ultimately independent from but parallel to the real atmosphere.

One of the challenges of an OSSE is to demonstrate that the NR does have the same statistical behavior as the real atmosphere in every aspect relevant to the observing system under scrutiny. For example, an OSSE for a wind-finding lidar aboard a satellite requires a NR with a realistic cloud climatology because lidars operate at wavelengths for which thick clouds are opaque. The cloud distribution thus determines the location and number of observations.

The NR is also the source of simulated observations. For each observing system, existing or future, a set of realistic observing times and locations is developed, along with a list of observed parameters. An interpolation algorithm looks at the accumulated output of the NR, goes to the proper time and location, and then extracts the value of the observed parameter. If the NR did not explicitly provide the observed parameter, the parameter is estimated from related variables that the model does provide. Because observations extracted from the NR are equal to the defined truth (they are 'perfect'), various sources of error must also be simulated and added to form observations with realistic accuracy with respect to the NR itself.

4.1 Joint OSSE Nature Run

The NRs and simulated data ought to be shared between many institutes carrying out the actual OSSEs. OSSEs with different NRs are difficult to compare but OSSEs using different DAS and the same NR can provide a valuable crosscheck of data impact results.

The primary specifications of the new NR are, thus, that it:

a. Covers a long enough period to span all seasons and to allow selection of interesting sub-periods for closer study;
b. Provides data at a temporal resolution higher than the OSSE analysis cycle;
c. Simulates the atmosphere at scales compatible with the main OS;
d. Uses daily SSTs;
e. Has user-friendly archiving.

Based on the recommendations from NOAA and NASA, ECMWF produced a new NR in July 2006 at T511 (40 km) spectral truncation and 91 vertical levels, with the output saved every 3 hours. Two high resolution NRs at T799 (25km) horizontal resolution and 91 vertical levels have been generated to study data impacts when forecasting hurricanes and midlatitude storms. The output is saved every hour. A hurricane period from September 27 to November 1 was selected. A period from April 10 to May 15 was selected to study midlatitude storms. The version of the model used was the same as the interim reanalysis at ECMWF (cy30r1). The initial condition is the operational analysis on 12Z May 1st, 2005 and the NR ends at 00Z June 1st, 2006. The model was forced by daily SST and ice provided by NCEP (also used in the operational forecasts) which is used throughout the experiments. [6]

The complete data for the T511NR and T799NR are saved at ECMWF, NCEP, NASA/GSFC, and ESRL. Access to the complete NRs is available from the NASA/GSFC/NCCS portal system. Access to the data from this site requires an account, which is available to the research community. The data at NCAR are part of the CISL Research Data Archive as data set ID ds621.0. Currently, an NCAR account is required to access the data. The complete NRs will also be available from ECMWF. Verification data for the T511NR are saved at the NCAR/CISL Research Data Archive and JMA. Complete verification data are also available from NRL/Monterey, Univ. of Utah, and Mississippi State University.

2.2 Evaluation of the Nature Run

Midlatitude cyclone statistics were produced using Goddard’s objective cyclone tracker. Distribution of cyclone strength across the pressure spectrum, cyclone lifespan, cyclone deepening, regions of cyclogenesis and cyclolysis, distribution of cyclone speed and direction are studied. All statistics showed the NR is within interannual variability. Location and intensity of the jet, and cloud cover were also evaluated and found to be much improved from any other nature runs. (Fig. 1)

Once over the Atlantic Ocean, signs of the development and organization of some waves into smaller-scale circulations are observed. In particular, the ECMWF NR seems to also show the capability of spontaneously (without any form of vortex bogusing, relocation or ad-hoc data assimilation) producing realistic Atlantic hurricanes. One example is depicted in Fig 5, where zonal and meridional vertical cross-sections are shown relative to a vortex positioned at 29N 83W at 21z 26 Aug 2005. Despite an interpolation at 1x1 degrees, the vortex looks very realistic, with a prominent warm core and vertically aligned isotachs indicating an eye-like feature. Low-level winds exceed 45 m/s, which is a very respectable speed for a 1x1 degree resolution data set.

These findings, albeit preliminary, are suggestive that the ECMWF NR simulates a realistic meteorology over tropical Africa and the nearby Atlantic and may prove itself beneficial to OSSE research focused over the AMMA or the Atlantic Hurricane regions. [7]

5. Concluding remarks

OSSEs are a challenge to the scientists in the field of meteorology. Operational centers are busy in getting the best possible value out of existing instruments. Carefully designed OSSEs will enable scientists to make strong and important contributions to the decision making process for future OSs. Time will be saved in utilizing the new data compared to the work required for OSs that were built without any back up from OSSEs. However, there is a serious dilemma in spending resources on OSSEs. If you spend your resources on getting the greatest benefit out of existing data sources, you miss the opportunity to critique future OSs and then you have to live with what you get ten years later. If you spend all your resources on OSSEs, you will be criticized for letting today's valuable data fall on the floor.

OSSEs will be a great challenge to the leadership and organizations. OSSEs require strong leadership with a clear vision, because many of the efforts have to be performed against short-term benefit. Although operational systems are supposed to benefit from a development OSSE system which will reduce the cost of implementation, there are immediate costs with OSSEs.

OSSEs will require the development of good communication. It is great deal of work to implement a new element into operational suites. It is important to maintain the parallel structure between the DA system for OSSEs and the operational DA system as much as possible and keep updating and testing operational facilities in OSSEs. Many experimental facilities could be developed through OSSEs. However, these facilities cannot be used if they are not developed according to the operational coding standards. Very close coordination between the OSSE effort and operational work is very important to having a valuable outcome from OSSEs.

Finally, as the experience in OSSEs at NCEP has demonstrated, OSSEs often produce unexpected results. Theoretical prediction of the data impact and theoretical back up to the OSSE results are very important. On the other hand, unpredicted OSSE results stimulate further theoretical investigation. When all efforts come together, OSSE will help with timely reliable recommendations for future OSs. At the same time, OSSEs will prepare the operational DA system to promote the prompt and effective use of the new data.

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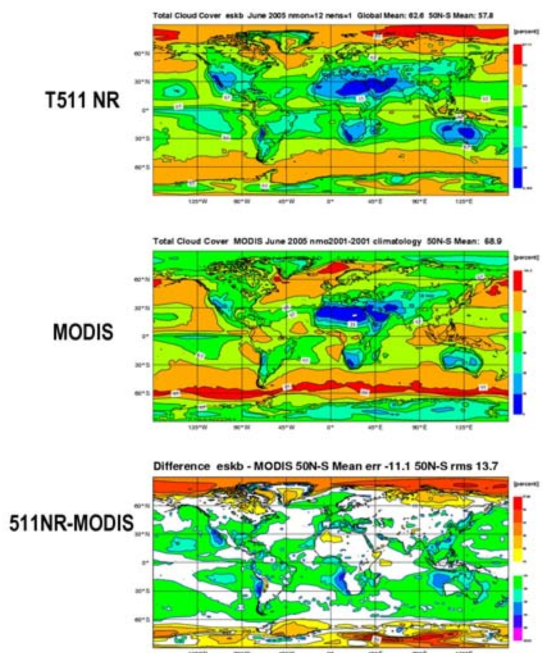

Fig. 1 Annual mean total cloud cover. T511NR and observed estimate from MODIS data.