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# Observing system simulation experiments at NCEP

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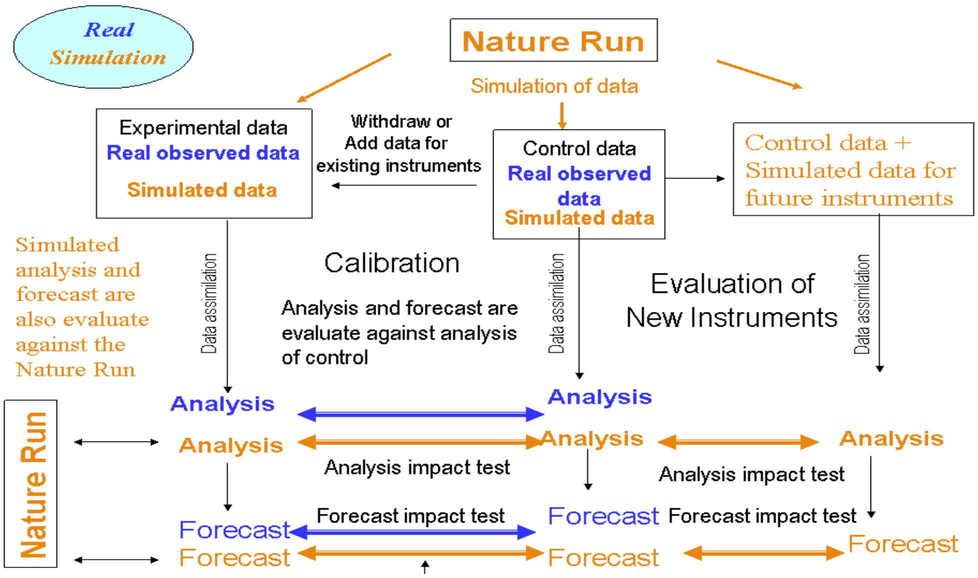
## 1. Introduction

Through the NPOESS OSSE project, future observing systems will be designed to optimize use of data assimilation systems (DA) and forecast systems to improve weather forecasts for the maximum societal and economic impact. Data assessment using simulation experiments will allow quantitative evaluation of future observing systems and instruments. These experiments are known as Observing System Simulation Experiments (OSSEs). By using OSSEs, current operational data assimilation systems can be prepared to handle new data and the operational use of data from future instruments and observing systems can be accelerated.

Preparations include handling the volume of future data and the development of data base, data processing (including formatting), and quality control systems. All of this development will accelerate the operational use of the data. An OSSE for the global observing system, in particular the Doppler Wind Lidar (DWL), was conducted at NCEP in collaboration with NESDIS, Simpson Weather Associates (SWA), and NASA. The OSSE system, procedures and selected results have been presented by Masutani et al., (2004). To date, the major effort in this project was the development of a simulated prototype Doppler wind lidar (DWL) data set. SWA has been able to simulate line-of-sight (LOS) winds using their Lidar Simulation Model (LSM). Bracketing sensitivity experiments were performed for various DWL technology neutral concepts to bound the potential impact. Scanning and various data sampling strategies were tested with these experiments. The impacts of DWL on analyses and forecasts have been presented (referenced articles in Masutani et al., (2004)). In this paper, recent results from OSSEs using a higher resolution model are presented. The recent development of international collaborative OSSEs and challenges in OSSEs are discussed.




## 2. The OSSE system used at NCEP

The Nature Run (NR) used for these experiments was provided by ECMWF. The model used for the NR is the same as the ECMWF 15 year reanalysis with T213 horizontal resolution and 32 levels. Conventional observations are simulated at same locations as in the 1993 distribution. Satellite radiance data are simulated for NOAA 11 and NOAA 12. These simulated data for 1993 were used for the calibration of OSSEs. The data impacts of the simulated data were compared with that of real data as of 1993, using the 1999 version of DA at T62 resolution. Many OSSEs for DWL were performed with this system and the results are presented in Masutani et al., (2004). DA for OSSE was upgraded to the 2003 operational system and experiments with T170 and T62 resolution were performed to study the impact of model resolution.

### 3. Data impact and model resolution

The impact of DWL has been evaluated using a T62 resolution model. However, there many reasons to expect that data impact using a higher resolution model is different. When using a higher resolution model (or better forecast models), the background fields are much better and there is less room for data to improve the analysis. On the hand, the higher resolution model will be able to utilize a finer detail of data efficiently and that will lead to higher data impact.

A comparison between T62 and T170 model resolutions was performed without radiance data. NOAA 11 and NOAA 12 had not been added to the new fast radiative transfer model in the SSI, but are now included in future OSSEs for calibration purposes. Since it is not possible to discuss a meaningful data impact in the Southern Hemisphere without satellite radiance data, only Northern Hemisphere results are presented in this report. The impact of TOVS radiance was discussed using the 1999 version of SSI, and showed the benefit from using both radiance and DWL data together.

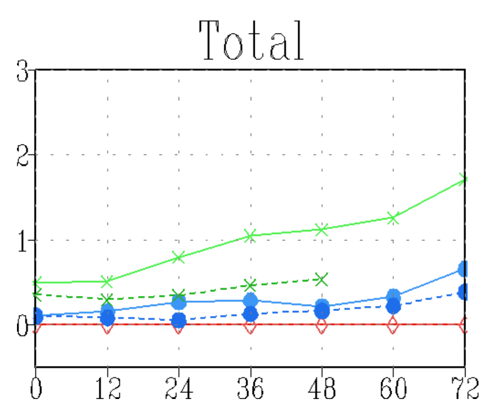
The data impact is presented for 200mb V fields. The 200mb V shows a synoptic wave formed over a midlatitude jet which is a component of momentum and temperature flux that control global circulations. The impacts are discussed for total waves (wave number scales 1-20) and synoptic scale waves (wave number 10-20).

Hybrid DWLs with scan and non-scan are tested with T62 and T170 resolutions. Data impacts are reduced in T170 (Fig 1) because a T170 model can produce better forecasts with much less data (Fig.2). However, the data impact in the T62 experiments shows an erroneous impact in the North Pole region which disappeared in the T170 experiments. If the model is poor it easily produces a large analysis impact, but the large analysis impact rapidly decreases with forecast time. If the model is sufficiently good, small analysis impacts will grow with forecast time.

The impact of increasing the model resolution to T170 is comparable to the hybrid DWL impact for the total scale. However, in the synoptic scales, the impact of DWL exceeded that from the improvement to T170 (Fig. 2).

These results are affected by the way DWL data are prepared. DWL data are prepared as an area average with a 200km radius or a 200km uncertainty in position. In order to reduce the observational error in DWL data, averaging needs to be performed. If DWL can produce better resolution data, the advantage of a high resolution model will increase.

Apparent data impact is less in a high resolution model (T170 or better model) because the guess is already good. However, improvement from the new data becomes more robust in high resolution model. Much of the apparent improvement in a low resolution model diminishes in the forecast fields.



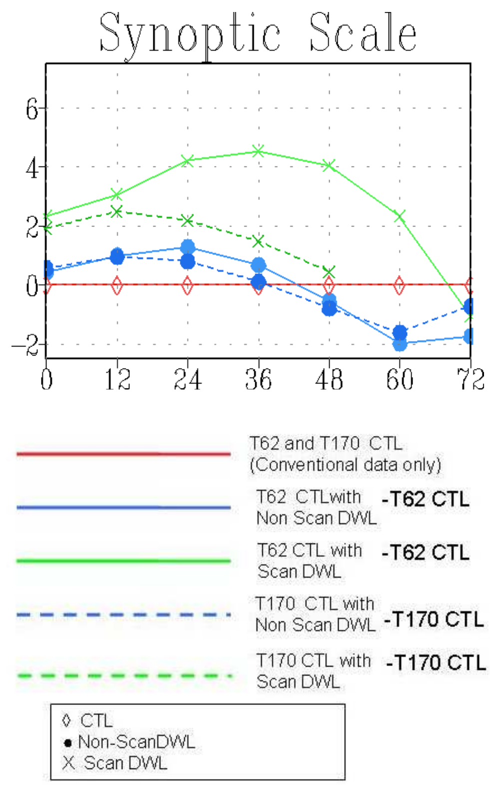
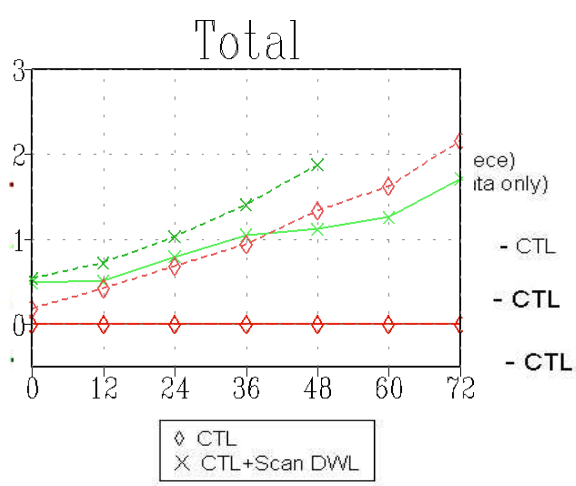
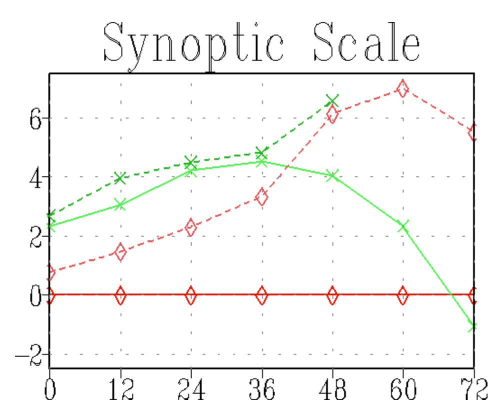



Fig.1. Anomaly correlations (AC) with Nature Run for 200mb meridional wind. The difference from AC for CTL (solid line ◊) shows the forecast impact of DWL with scanning (x) and non-scanning (●). CTL experiments (◊) include only conventional data. Top panel includes all waves; bottom panel includes wave numbers 10-20 only (synoptic scale). Period used is Feb 13-20. Solid lines are for T62 experiments; dashed lines are for T170 experiments.



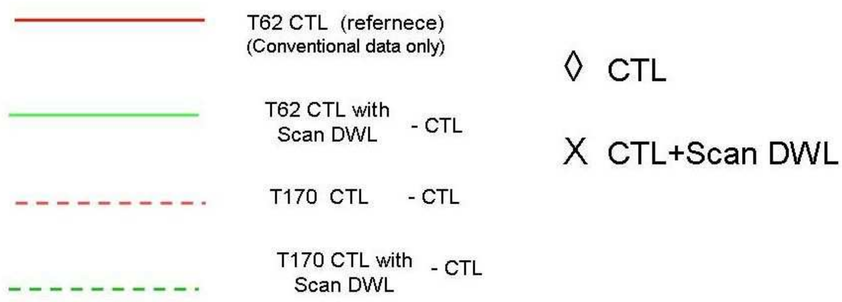



Fig.2. Anomaly correlations (AC) with Nature Run for 200mb meridional wind. The difference from AC for T62 CTL (solid line ◊) shows the forecast impact of T170 CTL and DWL with scanning (x). CTL experiments (◊) include only conventional data. Top panel includes all waves; bottom panel includes wave numbers 10-20 only (synoptic scale). Period used is Feb 13-20. Solid lines are for T62 experiments; dashed lines are for T170 experiments.

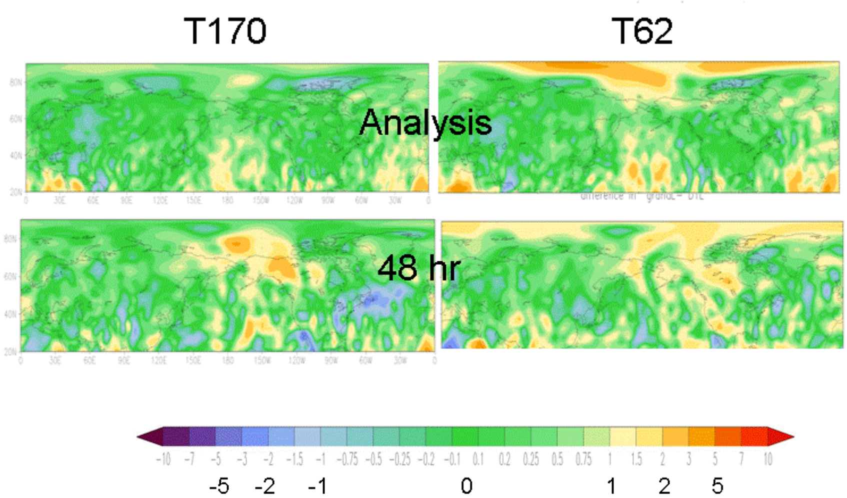



Fig.3 Impact of a space based Doppler Wind Lidar with scanning on 200hPa V-component fields.

## 4. Extending the collaboration

The Joint Center for Satellite Data Assimilation (JCSDA) recognized OSSEs as a key program element for the center. JCSDA has nominated several candidate instruments to be simulated including CrIS, ATMS, GOES-R/GIFTS and the HyMS – P and G.

NCEP needs to develop the system to assimilate these data in order to conduct the OSSEs. NCEP will collaborate with JCSDA to conduct OSSEs for advanced satellite sensors that will be used for weather and climate analysis and prediction.

International collaboration is also expanded through THORPEX project. The leadership of these collaboration depends on future development.

## 5. Seek the next Nature Run

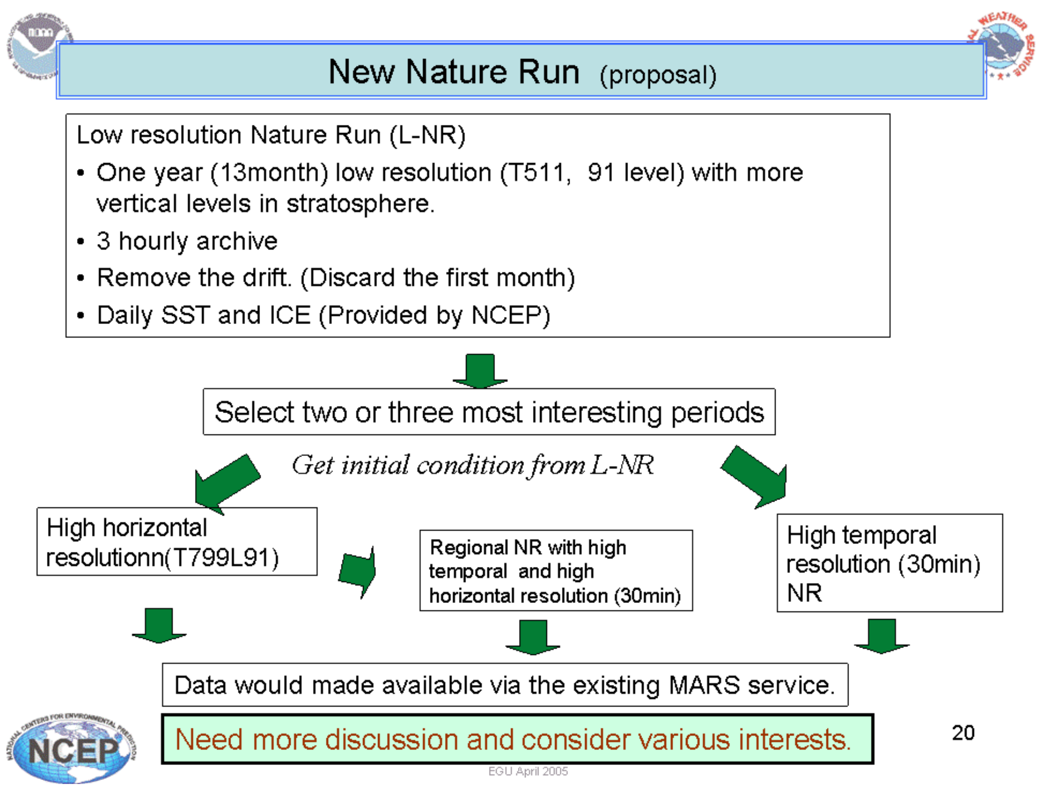
It is evident that the OSSE with its current nature run is limited. The new data need to be tested with at least a T170 model resolution, but the T213 NR produced by ECMWF is too coarse to be used for OSSEs with the higher resolution model.

We found the preparation of the NR and simulation of data consumes significant resources. It is desirable to have one or two good NRs and the data to be simulated created by one or two institutes. NRs and simulated data must be shared with many different institutes and OSSEs. OSSEs with different NRs are difficult to compare but OSSEs with different DAs but the same NR produce a valuable evaluation of data impact.

The basic features of this proposed NR are:

a. Cover a long period to allow selection of the most interesting periods;
b. Use daily SSTs;
c. Use a high special and/or temporal resolution NR for the selected periods;
d. Include user friendly archiving.

The details require further discussion. ECMWF has agreed that they should be able to produce the NR proposed above.




## 6. Discussion and strategies of OSSE and Future Plans

Much research has shown that wind information has a much stronger impact on weather forecasts than temperature. The results from NCEP OSSEs support these results in many ways. If DWL could provide three dimensional wind data, it would cause a fundamental advance in the prediction of weather (Baker et al., 1995). Another advantage of DWL is its ability to take direct measurements of the wind, while radiative transfer models and many other complicated processes are required to extract temperature information from radiance data. The winds derived from temperature lack information about the divergent components.

On the other hand, space-based DWL is a costly instrument and careful evaluation through OSSEs is important. Once OSSE systems are developed, they can be used to develop other instruments with relatively little effort.

It is a challenging task to evaluate the realism of the impacts from OSSEs, due to uncertainties in OSSE. The differences between the NR and the real atmosphere and the various assumptions involved in simulating data and assimilating data all affect the results. Evaluation metrics also affect the conclusion. Therefore, it is important that the results are evaluated from various perspectives. For example, it is found that the results depend on the error assigned to the data. Masutani et al., (2004) showed that correlated large scale errors added to the simulated data increased the data impact in the large scale but did not significantly change the data impact in synoptic scales.

NCEP's OSSE has demonstrated that carefully conducted OSSEs are able to provide useful recommendations which influence the design of future observing systems. Consistency of results within OSSEs is important. Some results may be optimistic and some are pessimistic. Consistency in the results will allow credible interpretation of the results from OSSEs.

If the inconsistencies are not explained, interpretation becomes difficult. For the NCEP OSSE, DWL data is simulated and assimilated as LOS. Level 1B radiance data are simulated and assimilated using a different radiative transfer model. On the other hand, sometimes temperature is interpolated from the NR to locations where the retrieved temperature is used as proxy sounding instruments. (Atlas 2004) DWL data are also evaluated as horizontal wind components. The impact based on these data requires great care and investigation.

Simulation of more realistic DWL configurations was proposed by SWA. Sensitivity to the quality of simulated observations and the assumed data quality in the analysis will be investigated.

NCEP's OSSE system has recently been transferred to a more powerful computing environment to accommodate data assimilation using higher resolution models and high density radiance data. AQUA data have already been simulated by NESDIS (Kleespies et al., 2003) and initial experiments performed. The initial simulation of Cross Track Infrared Sounder (CrIS) data and ATOVS are also complete. However, a data assimilation system has to be developed to assimilate these newly simulated data. Once an OSSE has been started for these data, iterations of experiments may be required to achieve confidence in the results.

Research related to adaptive observing strategies and some fundamental issues in the design of observing networks will be conducted to estimate the upper bound of forecast impacts from various observing strategies, if the necessary support is provided.

All these efforts in data assimilation will help in the designing of future observing systems and accelerate the actual use of new data after the data become available.

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