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Collaboration on Observing System Simulation Experiments (Joint OSSE)

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Collaboration on Observing System Simulation Experiments (Joint OSSE)

Erik Andersson, Michiko Masutani

To decide how to develop the meteorological observing systems the benefit of the new observations needs to be accurately assessed; such information helps determine which systems and instruments to investment in and which will provide best value for money. Use of observing system simulation experiments (OSSEs) is a well-established technique providing objective and quantitative evaluation of future observing systems and instruments.

Simulation experiments use a model-generated proxy for the real atmosphere, commonly called the 'Nature Run'. This defines the evolution of the atmosphere over the entire experimental period. Simulated observations are generated from the Nature Run, and used in data assimilation experiments where their impact on analysis and forecast accuracy can be assessed. In such idealized experiments, the Nature Run also provides the 'truth' which all results are verified against.

An internationally collaborative effort called Joint OSSE has formed over the last several years in order to perform OSSEs (*Masutani et al.*, 2007). The Nature Run for the Joint OSSE was produced by ECMWF.

Assessing impact of future observations

OSSEs are very labour intensive projects. The Nature Run (hereafter referred to as NR) has to be produced using a state of the art NWP model at the highest resolution feasible. In addition:

- The simulation of observations from a NR requires large computing resources.
- Simulations and assimilations may have to be repeated using more than one configuration to achieve a recommendation with confidence.
- OSSEs require expert knowledge in modelling, data assimilation and observing system technology.

Consequently, efficient and effective collaboration is essential for sharing the workload and producing reliable results.

Ideally, every proposed observing system should be tested by OSSEs before being selected to be built. OSSEs can be important in influencing the configuration of an observing system and the design of a satellite instrument. Subsequently, while the instruments are being built, OSSEs can help prepare both the science and the software of NWP data assimilation systems for the new observation types.

Some institutions in the USA referred to in this article

- **JCSDA:** Joint Center for Satellite Data Assimilation
- **NASA/GLA:** NASA's Goddard Laboratory for Atmospheres
- **NASA/GMAO:** NASA's Goddard Global Modeling and Assimilation Office
- **NASA/GSFC:** NASA's Goddard Space Flight Center
- **NASA/SIVO:** NASA's Software Integration and Visualization Office
- **NCAR/CISL:** NCAR's Computational and Information Systems Laboratory
- **NCEP/EMC:** NCEP's Environmental Modeling Center
- **NESDIS/ORA:** NESDIS's Office of Research and Applications
- **NOAA/ESRL:** NOAA's Earth System Research Laboratory
- **NOAA/NCEP:** NOAA's National Centers for Environmental Prediction
- **SWA:** Simpson Weather Associates, Inc.

AFFILIATIONS
Erik Andersson: ECMWF, Reading, UK
Michiko Masutani: NOAA/NWS/NCEP, Camp Springs, USA

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The Joint Center for Satellite Data Assimilation (JCSDA), Washington, recognized that it is very important that future observing systems be tested by OSSEs. Now NCEP/EMC, NASA/GMAO, JCSDA, ECMWF, NESDIS/ORA, NASA/SIVO, NASA/ GLA, SWA, NOAA/ESRL (Boulder), KNMI, and others are working together to further this goal. The Japan Meteorological Agency, Météo-France and the Met Office (UK) are also participating in this effort (*Masutani et al.*, 2007).

Joint OSSE Nature Runs

The starting point of an OSSE is the Nature Run, which serves as 'truth' for the simulations. The team behind the Joint OSSE decided to use a long forecast from ECMWF, forced with daily sea-surface temperature and sea ice, as the NR. It is unavoidable that the NR gradually diverges from the real atmosphere during the first few weeks of the forecast. This is not a concern within the context of an OSSE, provided that the climatological statistics of the simulation match those of the real atmosphere.

The main NR is a 13-month forecast using cycle 30r1 of ECMWF's Integrated Forecasting System (IFS) with T511 horizontal resolution (40 km) and 91 levels in the vertical; the output is saved every 3 hours. The initial condition is the operational analysis on 12 UTC on 1 May 2005 and the NR ends at 00 UTC on 1 June 2006.

The T511 NR was evaluated, and very realistic hurricanes (Figure 1) and mid-latitude cyclone statistics were reported (*Masutani et al.*, 2007; *Reale et al.*, 2007). The cloud distribution is much more realistic than in the previous NR (*Masutani et al.*, 1999). Statistics of the mid-latitude jet were also studied and found to be realistic. Further reports on the validation of T511 NR are available at:

http://sivo.gsfc.nasa.gov/OSSE/nature_run_validation.html

They include studies of how well it captures the South American and African monsoons, and tropical and mid-latitude cyclones.

Two high-resolution NRs at T799 horizontal resolution with 91 vertical levels have been generated to study data impact on forecasting hurricane and mid-latitude storms. A hurricane period from 27 September to 1 November was selected. A period from 10 April to 15 May was selected to study mid-latitude storms.

The NRs are accompanied by an additional dataset of low-resolution pressure and isentropic level data on a latitude-longitude grid, also provided by ECMWF, to speed up the diagnostic and evaluation processes. Selected surface variables from the T511 NR and all surface variables from the T799 NR are provided on a regular latitude-longitude grid. Furthermore, a time series of selected variables on a regular grid is also provided. The gridded data is used for verification purposes only and observations must be simulated from the full-resolution model-level data.

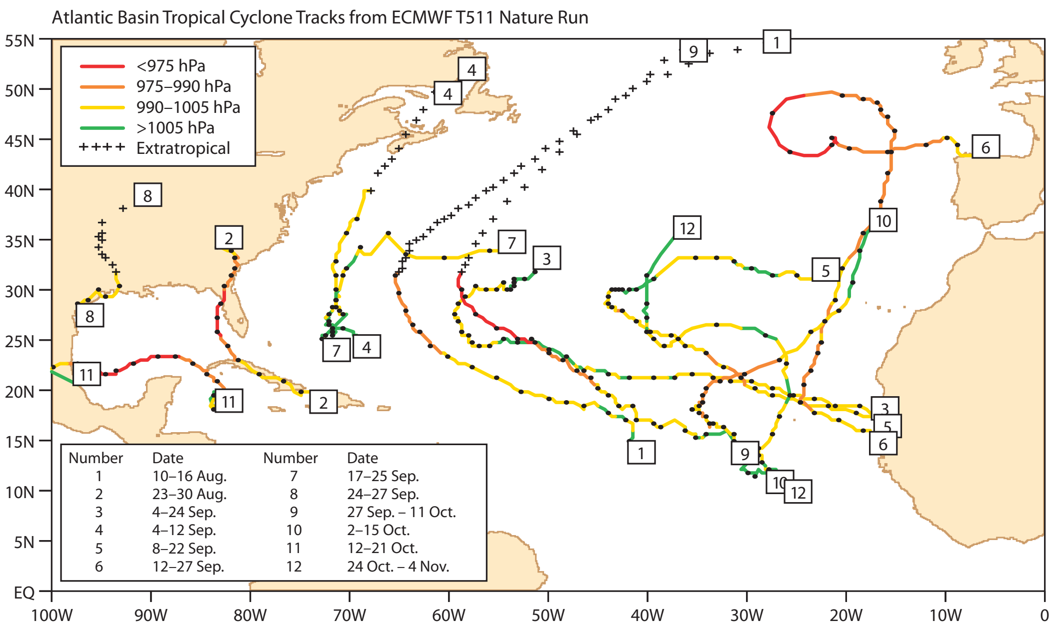

Figure 1 Atlantic tropical cyclones in the Nature Run 'hurricane season'. The tracks are shown in different colours reflecting the centre pressure in the full resolution T511 surface fields. Crosses indicate extratropical storms. From *Reale et al.* (2007).

Data distribution, usage and credit

The complete data for the T511 NR and T799 NR is saved at ECMWF, NCEP, NASA/GSFC, and NOAA/ESRL. Also verification data for the T511 NR is saved at the NCAR/CISL Research Data Archive and Japan Meteorological Agency.

NR data is available from ECMWF for the ECMWF registered users, from NASA/GSFC in the USA, and from the NCAR/CISL Research Data Archive. Access to the complete NRs is available from the NASA/GSFC portal system. Currently the data is available from:

http://sivo.gsfc.nasa.gov/OSSE/index.html

Access to the data from this site requires an account, which is available to the research community. This data must not be used for commercial purposes and re-distribution rights are not given. ECMWF and Joint OSSE must be given credit in any publications in which this data is used.

Methodology

For OSSEs, the NR is a proxy for the real atmosphere. It is from the NR dataset that simulated observations are generated. As with real observations measured in the real atmosphere, simulated observations are assimilated both with and without certain observing systems included. Forecasts are then executed from these assimilations. The output from both the assimilations and forecasts are evaluated in a variety of ways. The results of the evaluation can be used to either calibrate the OSSE system to enhance realism, or to tune various components of the system to improve performance.

In the initial iterations through this cycle, comparisons are made between experiments using simulated and real observations, both using the same data assimilation system and forecast model. Inconsistencies in results between the simulated world and real world may necessitate a calibration of one or more components of the OSSE system. Calibration may involve, for example, improving the errors that are applied to the simulated observations or enhancing certain NR fields to achieve greater realism.

After the initial calibration is performed, the OSSE system is ready for actual experiments with new observing systems. At this point, another iterative process will commence in which simulated observations from new instruments are introduced. Results of assimilations and forecasts with and without these new observations are evaluated. The NR provides the truth data against which all of these simulated experiments are verified.

Progress in simulation of observations and precursor assimilation

Conventional and radiance data has been simulated from the T511 NR for an entire year at NOAA/NCEP. This data is available to Joint OSSE participants. The observations are being produced with simulated observational errors, which roughly correspond to the types of random errors found in real observations. This is an essential component of the impact assessment: if the errors are too small then the resulting OSSE results will show unrealistic benefit from the data.

Since the spatial drift of radiosondes (RAOBs) is considered in the NCEP data assimilation system, it has to be simulated in the NRs as well. The drift was not significant for previous OSSEs with a low resolution NR, though it becomes significant at the resolution scales of T511 (40 km) or T799 (25 km). Extensive discussions on representativeness errors have been organized under the auspices of the Joint OSSE.

The current state of the OSSEs is as follows.

- Simulations of an Unmanned Aircraft System (UAS) are funded and the simulation is in progress at NOAA/ESRL.
- Simulations of a Doppler Wind Lidar satellite system are funded and in progress at KNMI, NASA and SWA.
- KNMI is seeking funding to simulate scatterometer data.

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The challenge

It is a challenging task to evaluate the realism of impacts from OSSEs as the results are affected by uncertainties in an OSSE, the differences between the NR and real atmosphere, the process of simulating data, and the estimation of observational errors. The choice of evaluation metrics also affects the conclusions drawn.

Consistency in results is important. However, it is also important to be able to evaluate the source of the errors and uncertainties. As more information is gathered we can perform more credible OSSEs. If the results are inconsistent, the cause of the inconsistency needs to be investigated carefully. NCEP's OSSEs have demonstrated that carefully conducted OSSEs are able to provide useful recommendations to influence the design of future observing systems (wind lidars). OSSEs are able to provide guidance on where more observations are required and where the model needs to be improved.

OSSEs will be conducted by various scientists with different interests. Some are investigating the potential applications of particular prospective instruments. Others may want to aid in the design of the global observing system.

At the current time, the American space agencies are getting involved in prioritising and funding the most urgent impact simulations from their perspective. Now that the Joint OSSE framework has been built and validated, there is a wide range of possibilities for its application.

Further reading

Masutani, **M.**, **K. Campana**, **S. Lord** & **S.-K. Yang**, 1999: Note on Cloud Cover of the ECMWF nature run used for OSSE/NPOESS project. *NCEP Office Note No.427*.

Masutani, **M.**, **E. Andersson**, **J. Terry**, **O. Reale**, **J.C. Jusem**, **L.-P. Riishojgaard**, **T. Schlatter**, **A. Stoffelen**, **J.S. Woollen**, **S. Lord**, **Z. Toth**, **Y. Song**, **D. Kleist**, **Y. Xie**, **N. Priv**, **E. Liu**, **H. Sun**, **D. Emmit**, **S. Greco**, **S.A. Wood**, **G.-J. Marseille**,**R. Errico**, **R. Yang**, **G. McConaughy**, **D. Devenyi**, **S. Weygandt**, **A. Tompkins**, **T. Jung**, **V. Anantharaj**, **C. Hill**, **P. Fitzpatrick**, **F. Weng**, **T. Zhu** & **S. Boukabara**, 2007: Progress in Joint OSSEs. In *AMS Preprint Volume for 18th Conference on Numerical Weather Prediction*, Parkcity UT, 25–29 June 2007.

Reale, **O.**, **J. Terry**, **M. Masutani**, **E. Andersson**, **L.P. Riishojgaard** & **J.C. Jusem**, 2007: Preliminary evaluation of the European Centre for Medium-Range Weather Forecasts' (ECMWF) Nature Run over the tropical Atlantic and African monsoon region. *Geophys. Res. Lett.*, **34,** L22810, doi:10.1029/2007GL031640.

The list of OSSE related references are available at:
http://www.emc.ncep.noaa.gov/research/JointOSSEs/references/

NASA OSSE home page:
http://sivo.gsfc.nasa.gov/OSSE/index.html

THORPEX OSSE home page:
http://www.emc.ncep.noaa.gov/research/THORPEX/osse