15A.2

Progress in Joint OSSEs

Three Joint OSSE nature runs and simulation of observation

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1. Background

Observing system impact assessments using atmospheric simulation experiments are conducted to provide an objective quantitative evaluation of future observing systems and instruments. Such simulation experiments using a proxy true atmosphere, or Nature Run (NR), are known as Observing System Simulation Experiments (OSSEs, Arnold and Day 1986, Lord et al. 1997, Masutani et al. 2006). An internationally collaborative effort called Joint OSSEs was formed over the last two years in order to perform "full OSSEs" (Masutani et al. 2007). Various types of simulation experiments have been performed, but through full OSSEs, where a NR is produced by a free forecast run using a model different from the forecast model used for the data assimilation system (DAS), and calibration between the real and simulated data impact is performed.

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OSSEs are a very labour intensive project. The NR has to be produced using the state of the art NWP models at the highest resolution. Simulating data from a NR requires large computing resources. Simulations and assimilations have to be repeated using numerous configurations in order to achieve a recommendation with confidence. OSSEs also require expert knowledge in many areas, and expert knowledge is 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 an instrument and the configuration of an observing system. While the instruments are being built, OSSEs will help in preparing 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 done after the data become available. An OSSE effort demands that this same work be completed earlier, and that will speed up the actual use of the new data.

The Joint Center for Satellite Data Assimilation (JCSDA), a collaboration between NOAA and NASA, recognized that it is very important that future observing systems be tested by OSSEs. Now NCEP/EMC, NASA/GMAO, JCSDA, NESDIS/ORA, NASA/SIVO, NASA/ GLA, SWA, ECMWF, NOAA/ESRL (Boulder), KNMI, and GRI at the University of Mississippi are working together to further this goal. JMA, Meteo France, and the Met Office (UK) are also participating in this effort, which the contributors collectively call the "Joint OSSEs". (Masutani et al. 2007)

2. Joint OSSE Nature Runs

The important starting component of OSSE is the Nature Run, which serves as “truth” for the OSSEs. Through various previous OSSEs, it has been realized that the preparation of the Nature Run and simulation of observations consumes a significant amount of effort. It is important to have a reference Nature Run so that multiple groups doing OSSE’s can compare results. Using the same Nature Run and extensive international collaboration within the meteorological community are essential for timely and reliable OSSEs that will positively impact the design of future observing systems. The design of the NR was based on discussions within the Joint OSSE. The details are described in Appendix A.

Joint OSSE decided to use a free forecast run with daily SST and ice as a NR. 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 the 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.

The first 13 month-long NR has a horizontal resolution of T511 (40 km) spectral truncation with 91 vertical levels with the output saved every 3 hours. The length of the NR is 13 months long to cover an entire year and to allow a period for spin up from the analysis. The version of the model used was similar to the interim reanalysis at ECMWF (cy30r1). The initial condition is the operational analysis on 12Z May 1, 2005 and the NR ends at 00Z June 1, 2006. The model was forced by daily SST and ICE provided by NCEP (also used in their operational forecasts), which is used throughout the experiments.

The T511 NR was evaluated, and very realistic hurricanes and midlatitude 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 midlatitude jet were also studied and found to be realistic.

Two high resolution NRs at T799 horizontal resolution with 91 vertical levels have been generated to study data impact on forecasting hurricane and midlatitude storms. 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.

Grib1 was selected as the data format for the NR. It will have to be reformatted to grib2 before grib1 becomes obsolete. However, there are significant advantages in using grib1 at this stage, because most of software available is compatible with grib1. Model level data was provided on a reduced Gaussian grid instead of as spectral components. Conversion from spectral components to a grid requires significant computing resources and the software was not as general as expected.

It is very helpful that these NRs were accompanied by an additional data set of low resolution pressure and isentropic level data on a lat-lon grid, also provided by ECMWF, to speed up the diagnostic and evaluation processes. Selected surface variables from the T511NR and all surface variables from the T799NR are provided on a regular lat-lon grid. Furthermore, a time series of selected variables on a regular grid is also provided. These regular lat-lon gridded data are for verification purposes only and observations must be simulated from the full resolution model level data.

3. Data Distribution, Usage and Credit

The complete data for the T511NR and T799NR are saved at ECMWF, NCEP, NASA/GSFC, and ESRL. Verification data for the T511NR are saved at the NCAR/CISL Research Data Archive and JMA. NR data are available t from ECMWF to ECMWF member states, from NASA/GSFC in the US, and from the NCAR/CISL Research Data Archive. Access to the complete NRs is available from the NASA/GSFC portal system. The maintenance responsibility has been transferred from SIVO to GMAO. Currently the data are 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. The data at NCAR are part of the CISL Research Data Archive as data set ID ds621.0. Currently a NCAR account is required to access the data. The complete NRs will also be available from ECMWF.

This data must not be used for commercial purposes and re-distribution rights are not given. ECMWF and Joint OSSEs must be given credit in any publications in which this data is used. NCAR will track users and send the information to ECMWF and the Joint OSSE. If you are interested in using the data it is necessary to send an E-mail with the statement below, and your name and affiliation to Michiko Masutani (michiko.masutani@noaa.gov). Your name will be added to the user list, a notification sent to ECMWF and the necessary account will be arranged. User agreement: "I agree not to copy the ECMWF data or software provided by NCAR for the use of other persons, and I agree not to use these data and/or software for commercial purposes. ECMWF will be given credit in any publications in which these data and/or software are used. I understand that if other persons in my organization wish to use these data and/or software, they must also sign a copy of this agreement. "

4. Progress in Simulation of Observations and Precursor Assimilation

Conventional data have been simulated from the T511NR for an entire year at NOAA/NCEP. These data are available to Joint OSSE participants. The first set of observations is being produced without observational error. These data are expected to produce a very optimistic data impact. However, model errors are already included. This data set will also be useful in evaluating data distributions. Various errors will be gradually added to the observations and analyzed individually. An identical twin OSSE is also being considered to evaluate model error.

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

For development purposes, 91-level NR variables are processed at NCEP and interpolated to observational locations with all the information need to simulate data (OBS91L). OBS91L for all foot prints are produced for a few weeks of the T799 period in October 2005, and also for a thinned foot print for the entire period. NASA/GSFC and NESDIS are simulating radiance data. Thinning of the foot print is based on operational use of radiance data. The 91L are also available for development of a Radiative Transfer Model (RTM).

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

Precursor assimilations are being performed. A precursor assimilation is being performed with low resolution to check the OSSE system. It will provide initial conditions for OSSE experiments for specific periods, and a spin up for bias correction. The precursor run will be used for calibration as well.

5. Further OSSE applications

The THORPEX Pacific - Asian Regional Campaign (T-PARC) project plans to conduct OSSEs using the Joint OSSE Nature Run. The goal is to design the experimental setup for the field phase for certain instruments. Development of strategies for targeted observations is one of the focuses for T-PARC OSSEs. OSSEs for UAS are also planned.

It has been found that OSSEs are very powerful tool to study error characteristics in DAS (Errico et al.). Knowing the truth, with readily available observations, OSSE data will be very helpful in the development of DAS and RTM.

Although the Joint OSSE will concentrate on OSSEs using the existing three NRs for the next few years, there are demands for a higher resolution mesoscale NR as higher resolution models and data become available. A mesoscale NR could be regional, global (Satoh et al. 2007) or a variable resolution global model. If a regional model is used for either the NR or DAS, the effects of lateral boundary conditions have to be evaluated. An OSSE using regional DAS with a higher resolution model using the existing global NRs is strongly recommended before any regional NR is produced.

6. Summary

It is a challenging task to evaluate the realism of impacts from OSSEs. Due to the uncertainties in an OSSE, the differences between the 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. One criticism is that OSSEs would produce too optimistic a data impact but a simulated data impact could also be pessimistic. Consistency in results is important. However, it is 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. If the inconsistencies are not explained, interpretation of the results becomes difficult. NCEP's OSSEs have demonstrated that carefully conducted OSSEs are able to provide useful recommendations to influence the design of future observing systems. The advantages of scanning were clear from the results of the NCEP DWL OSSE. ESA is planning to use multiple non scanning lidars to capture the effects of scanning. NASA 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 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.

OSSEs will be conducted by various scientists with different interests. Some are investigating the potential applications of particular instruments. Others may want to aid in the design of a global observing system. Operational centers such as NCEP will perform the role of finding a balance among conflicting interests to seek an actual improvement in weather predictions.

The experience of recent OSSEs also demonstrated that OSSEs often produce unexpected results. Theoretical prediction of the data impact and a theoretical backing for the OSSE results are very important. On the other hand, unpredicted OSSE results 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 for the operational DAS to promote the prompt and effective use of the new data.

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Appendix A

Detailed Description of the Joint OSSE NRs

T511NR (study data impacts on large scale events)
Length: 13 months
Initial conditions: Operational analysis at 12z May 1, 2005
Horizontal resolution: T511
Number of vertical levels: 91
Period covered: May 1, 2005 - June 1, 2006
Frequency of archive: 3-hourly

T799Oct05 (five week long hurricane period)
Length: five weeks
Initial conditions: T511NR at 12z September 27, 2005
Horizontal resolution: T799
Number of vertical levels: 91
Period covered: September 27 - November 1,2005
Frequency of archive: hourly

T799Apr06 (season for mid-latitude severe storms)
Length: five weeks
Initial conditions: T511NR at 12z April 10, 2006
Horizontal resolution: T799
Number of vertical levels: 91
Period covered: April 10 - May 15,2006
Frequency of archive: hourly

Data Format

Grib1
Decoder is available at
http://www.ecmwf.int/products/data/software/download/gribex.html

Time Series

Time series of surface data on a 1deg x 1deg for both T799NR and T511NR
CP(Convective precipitation), LSP(Large Scale Precipitation) HCC,MCC,LCC, SD SKT, T2m, TD2m, U10m,V10m, and MSLP

Time series of all surface data on a 0.5 deg x 0.5 deg for T799 NR
Surface height on a 1deg x 1deg for May 1, 2005 at 12z

Variables
Model level data:
Reduced Gaussian grid used for model
N256 for T511NR (1024 grid point around the equator)
N400 for T799NR (1600 grid point around the equator)

91-level data:

Uhbl	131	U velocity [m s**-1]
Vhbl	132	V velocity [m s**-1]
VOhbl	138	Vorticity (relative) [s**-1]
Whbl	135	Vertical velocity [Pa s**-1]
Thbl	130	Temperature [K]
O3hbl	203	Ozone mass mixing ratio [kg kg**-1]
CChbl	248	Cloud cover [(0 - 1)]
CIWChbl	247	Cloud ice water content [kg kg**-1]
CLWChbl	246	Cloud liquid water content [kg kg**-1]
Dhbl	155	Divergence [s**-1]
Qhbl	133	Specific humidity [kg kg**-1]
no100hbl	100	Geopotential height

Single level data:

LNSPhlev1	152	hybrid level 1 Logarithm of surface pressure
Zhlev1	129	hybrid level 1 Geopotential [m**2 s**-2]

Surface data:
Reduced Gaussian grid used for model.
N256 for T511NR (1024 grid point around the equator)
N400 for T799NR (1600 grid point around the equator)

no10Usfc	165	10 metre U wind component [m s**-1]
no10Vsfc	166	10 metre V wind component [m s**-1]
no2Dsfc	168	2 metre dewpoint temperature [K]
no2Tsfc	167	2 metre temperature [K]
ASNsfc	32	Snow albedo [(0-1)]
BLDsfc	145	Boundary layer dissipation [W m**-2 s]
BLHsfc	159	Boundary layer height [m]
CAPEsfc	59	Convective available potential energy [J kg**-1]
CHNKsfc	148	Charnock
CIsfc	31	Sea-ice cover [(0-1)]
CPsfc	143	Convective precipitation [m]
Esfc	182	Evaporation [m of water]
ESsfc	44	Snow evaporation [m of water]
EWSSsfc	180	East/West surface stress [N m**-2 s]
FALsfc	243	Forecast albedo [(0 - 1)]
FLSRsfc	245	Forecast log of surface roughness for heat
FSRsfc	244	Forecast surface roughness [m]
GWDsfc	197	Gravity wave dissipation [W m**-2 s]
HCCsfc	188	High cloud cover [(0 - 1)]
LCCsfc	186	Low cloud cover [(0 - 1)]
LGWSsfc	195	Lat. component of gravity wave stress [N m**-2 s]
LSMsfc	172	Land/sea mask [(0, 1)]
LSPsfc	142	Stratiform precipitation [m]
LSPFsfc	50	Large-scale precipitation fraction [s]
MCCsfc	187	Medium cloud cover [(0 - 1)]
MGWSsfc	196	Meridional component of gravity wave stress [N m**-2 s]
MSLsfc	151	Mean sea-level pressure [Pa]
NSSSsfc	181	North/South surface stress [N m**-2 s]
PARsfc	58	Photosynthetically active radiation at the surface [W m**-2]
ROsfc	205	Runoff [m]
RSNsfc	33	Snow density [kg m**-3]
SDsfc	141	Snow depth [m of water equivalent]
SFsfc	144	Snowfall (convective + stratiform) [m of water equivalent]
SKTsfc	235	Skin temperature [K]
SLHFsfc	147	Surface latent heat flux [W m**-2 s]
SMLTsfc	45	Snowmelt [m of water]
SRCsfc	198	Skin reservoir content [m of water]
SSHFsfc	146	Surface sensible heat flux [W m**-2 s]
SSRsfc	176	Surface solar radiation [W m**-2 s]

SSRCsfc	210	Surface net solar radiation, clear sky [W m**-2]
SSRDsfc	169	Surface solar radiation downwards [W m**-2 s]
SSTKsfc	34	Sea surface temperature [K]
STRsfc	177	Surface thermal radiation [W m**-2 s]
STRCsfc	211	Surface net thermal radiation, clear sky [W m**-2]
STRDsfc	175	Surface thermal radiation downwards [W m**-2 s]
SUNDsfc	189	Sunshine duration [s]
TCCsfc	164	Total cloud cover [(0 - 1)]
TCO3sfc	206	Total column ozone [Dobson]
TCWsfc	136	Total column water [kg m**-2]
TCWVsfc	137	Total column water vapour [kg m**-2]
TSNsfc	238	Temperature of snow layer [K]
TSRsfc	178	Top solar radiation [W m**-2 s]
TSRCsfc	208	Top net solar radiation, clear sky [W m**-2]
TTRsfc	179	Top thermal radiation [W m**-2 s]
TTRCsfc	209	Top net thermal radiation, clear sky [W m**-2]
UVBsfc	57	Downward UV radiation at the surface (Ultra-violet band B) [W m**-2]
Zsfc	129	Geopotential [m**2 s**-2]
var78sfc	78	Total column liquid water [kg m**-2]undefined
var79sfc	79	Total column ice water [kg m**-2]undefined
STL10_7cm	139	0-7 cm underground Soil temperature level 1 [K]
STL27_28cm	170	7-28 cm underground Soil temperature level 2 [K]
STL328_100cm	183	28-100 cm underground Soil temperature level 3 [K]
STL4100_255cm	236	100-255 cm underground Soil temperature level 4 [K]
SWVL10_7cm	39	0-7 cm underground Volumetric soil water layer 1 [m**3 m**-3]
SWVL27_28cm	40	7-28 cm underground Volumetric soil water layer 2 [m**3 m**-3]
SWVL328_100cm	41	28-100 cm underground Volumetric soil water layer 3 [m**3 m**-3]
SWVL4100_255cm	42	100-255 cm underground Volumetric soil water layer 4 [m**3 m**-3]
ISTL10_7cm	35	0-7 cm underground Ice surface temperature layer 1 [K]
ISTL27_28cm	36	7-28 cm underground Ice surface temperature layer 2 [K]
ISTL328_100cm	37	28-100 cm underground Ice surface temperature layer 3 [K]
ISTL4100_255cm	38	100-255 cm underground Ice surface temperature layer 4 [K]

Verification data are provided for pressure levels.
Regular lat lon on a 1deg x 1deg for T511 NR
Regular lat lon on a 0.5deg x 0.5deg for T799 NR

31 Pressure levels:
1000 975 950 925 900 850 800 775 750 700 650 600 550 500 450 400 350 300 250 200 150 100 70 50 30 20 10 7 5 3 2 1

Variables

CCprs	248	Cloud cover [(0 - 1)]
CIWCprs	247	Cloud ice water content [kg kg**-1]
CLWCprs	246	Cloud liquid water content [kg kg**-1]
Dprs	155	Divergence [s**-1]
O3prs	203	Ozone mass mixing ratio [kg kg**-1]
Qprs	133	Specific humidity [kg kg**-1]
Rprs	157	Relative humidity [%]
Tprs	130	Temperature [K]
Uprs	131	U velocity [m s**-1]
Vprs	132	V velocity [m s**-1]
VOprs	138	Vorticity (relative) [s**-1]
Wprs	135	Vertical velocity [Pa s**-1]
Zprs	129	Geopotential [m**2 s**-2]

Verification data on isentropic levels.
Regular lat lon on a 1deg x 1deg for T511 NR
Regular lat lon on a 0.5deg x 0.5deg for T799 NR

Five potential temperature levels: 315,330,350,370,530

Variables

Dtht	155	Divergence [s**-1]
MONTtht	53	Montgomery potential [m**2 s**-2]
O3tht	203	Ozone mass mixing ratio [kg kg**-1]
PREStht 54	Pressure [Pa]	
PVtht	60	Potential vorticity [K m**2 kg**-1 s**-1]
Qtht	133	Specific humidity [kg kg**-1]
Utht	131	U velocity [m s**-1]
Vtht	132	V velocity [m s**-1]
VOtht	138	Vorticity (relative) [s**-1]

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The list of OSSE related references are available at
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