OSSEs in the JCSDA

Presentation at AMS annual meeting


Impact of Different Wind Lidar Configurations on NCEP Forecast Skill. 16th Symposium on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface (IOAS-AOLS), Zaizhong Ma et al.

Posters
Internationally Collaborative Joint OSSEs - Progress At NOAA, T. N. Krishnamulti Symposium, Michiko Masutani (EMC) et al.

Joint OSSEs at NOAA, Evaluation of DWL, JPSS, and DWSS, Eighth Annual Symposium on Future Operational Environmental Satellite Systems, Michiko Masutani et al
Observing System Simulation Experiments in the Joint Center for Satellite Data Assimilation

Lars Peter Riishojgaard\textsuperscript{1,2}, Zaizhong Ma\textsuperscript{1,2}, Michiko Masutani\textsuperscript{3}, Jack Woollen\textsuperscript{3}, Dave Emmitt\textsuperscript{4}, Sid Wood\textsuperscript{4}, Steve Greco\textsuperscript{4}

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\textsuperscript{3}NCEP Environmental Modeling Center
\textsuperscript{4}Simpson Weather Associates
Role of a National OSSE Capability

- Impact assessment for future missions
  - Future operational observing systems (NOAA)
  - Decadal Survey and other science and/or technology demonstration missions (NASA)
  - Other agencies (e.g. DoD/DWSS)

- Objective way of establishing scientifically sound and technically realistic user requirements

- Tool for assessing performance impact of engineering decisions made throughout the development phases of a space program or system

- Preparation/early learning pre-launch tool for assimilation users of data from new sensors
Joint OSSE history

- NASA/NOAA collaboration started in 2007, involving NASA/GSFC, NOAA/NESDIS, NOAA/NWS, NOAA/OAR
- Centered around common use of Nature Run provided free of charge by ECMWF
- Coordinated through JCSDA
  - Informal, loosely structured nature, lack of common funding stream has presented challenges
- Successful joint validation of ECMWF Nature Run
- Some collaboration on simulation and calibration of observations
- ADM experiments (GMAO)
- GWOS experiments (JCSDA)
- UAS experiments (OAR)
Wind Lidar OSSEs

- Impact experiments for GWOS mission concept
  - NASA Tier-3 Decadal Survey mission concept
  - Four telescopes, full vector winds on either side of spacecraft
  - Two technologies, direct and coherent detection
- Experiments funded under Wind Lidar Science element of NASA’s ROSES 2007
- GWOS observations simulated by Simpson Weather Associates using DLSM
Which upper air observations do we need?

- Numerical weather prediction requires independent and global observations of the mass (temperature) and wind fields.

- The global three-dimensional mass field is well observed from space.

- No existing space-based observing system provides vertically resolved wind information => horizontal coverage of wind profiles is sparse.
Temperature profiles (AMSU; 6 hours)

ECMWF Data Coverage (All obs DA) - ATOVS
27/JUN/2007; 00 UTC
Total number of obs = 390343
Observed wind profiles (RAOBs, 6 h)

ECMWF Data Coverage (All obs DA) - TEMP
27/JUN/2007; 00 UTC
Total number of obs = 623
Doppler Lidar Measurement Concept

DOPPLER RECEIVER - Multiple flavors - Choice drives science/technology trades
- Coherent or heterodyne aerosol Doppler receiver
- Direct detection molecular Doppler receiver

Coherent 2 micron

LASER TRANSMITTER 355nm Direct detection

TELESCOPE

Molecules $\lambda_4$

Aerosols $\lambda_2$

Direct detection

Backscattered Spectrum

Frequency

Molecular $\lambda_4$

Aerosol $\lambda_2$
Hybrid Doppler Wind Lidar Measurement Geometry: 400 km

Return light: $t + 3.9$ ms, 30 m, 4.4 microrad

Second shot: $t + 200/10$ ms
1535/77 m, 227/11 microrad

First Aft Shot
$t + 190$ s

180 ns (27 m)
FWHM (76%)

414 km

90° fore/aft angle in horiz. plane

5 m (86%)

2 lines LOS wind profiles
1 line “horizontal” wind profile

45° azimut Doppler shift from S/C velocity
$\pm 3.7$ GHz
$\pm 22$ GHz

Max nadir angle to strike earth 70.2 deg

Ground spot speed: 7.2 km/s

$7.7$ km/s

292 km

400 km

400 km

585 km

45°

$0.2/0.01$ s = 1444/72 m
($2/0.355$ microns)
GWOS ISAL Instrument Quad Chart

Features of the Instrument Concept
- Utilizes Doppler lidar detection method
  - Coherent (aerosol) detection @ 2 \( \mu \)m
  - Direct (molecular) detection @ 355 nm
- Direct channel laser based on GLAS;
- Direct channel receiver based on TWiLiTE IIP
- Coherent channel laser and receiver based on DAWN IIP
- Telescopes are shared among all lasers
- Pointing and knowledge requirements met with co-located star tracker and GPS

Payload Data

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<tr>
<th>Feature</th>
<th>Value</th>
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<tr>
<td>Dimensions</td>
<td>1.5m x 2m x 1.8m</td>
</tr>
<tr>
<td>Mass</td>
<td>567 Kg</td>
</tr>
<tr>
<td>Power</td>
<td>1,500 W</td>
</tr>
<tr>
<td>Data Rate</td>
<td>4 Mbps</td>
</tr>
</tbody>
</table>

Technology Development Needs

- Direct detection system requires 6 billion shots for mission lifetime (2 years)
  - Direct channel baseline is 3 lasers + 1 backup
  - Demonstration of reliable performance at higher or lower lifetimes will determine number of lasers for direct detection channel, impacting mission cost
- Coherent detection system requires demonstration of the 316M shot lifetime in a fully conductively cooled laser
- Both Lidar technologies require aircraft validation flights
Data assimilation system(s)
- NCEP/EMC Global Forecast System (T-382) coupled with GSI

Nature run
- ECMWF T-511, commissioned for Joint OSSE
  - 13 month period (May 2005-June 2006)
  - Validated extensively through Joint OSSE collaboration

Simulated observations
- Reference observations, including satellite radiance data (all observation)
- Perturbation (“candidate”) observations
- GWOS observations simulated by Simpson Weather Associates

Diagnostics capability
- NCEP operational verification system
Experimental setup

- NCEP GFS at a range of horizontal resolutions between T-126 and T-382 (previous operational resolution at NCEP; NR cannot accommodate current T-574 resolution)
- “OSSE period”: July 01-Aug 15, 2005 (simulated)
  - Five-day forecast launched every day at 00Z
  - Most observing systems used for routine operational NWP included, except GPSRO and IASI (will be included once we simulate 2010/11 GOS)
- Four experiments, all verified against Nature Run
  - CRTL: Observations as assimilated operationally by NCEP
  - NOUV: as CTRL, but without RAOBS (220, 221 and 232)
  - NONW: as CTRL, but without any wind observations
  - DWL: as CTRL, plus simulated GWOS lidar wind data
- Experiments done with “perfect data”
  - No observation error added (simple random errors tested; no significant changes to conclusions)
  - Simulated with assumed observation errors used in operations
500hPa HGT anomaly correlation coefficients (T126)
500hPa HGT anomaly correlation coefficients (T382)

Impact of DWL observations is larger at the higher resolution (T382), even though skill of control is higher.
Time series of 500hPa geopotential height AC

Candidates for additional study
Special Case Study:
5 days forecast starting from July 31st

Open the link for the movies

http://www.emc.ncep.noaa.gov/seminars/presentations/2012/WLS_OSSE_20120214/fig_ctrl_100.gif

500hPa HGT DIFF of F120h starting at 2005073100 (CTRL-NR)

http://www.emc.ncep.noaa.gov/seminars/presentations/2012/WLS_OSSE_20120214/fig_dwl_100.gif

500hPa HGT DIFF of F120h starting at 2005073100 (DWL-NR)
RMSE: 200, 850hPa Wind error in tropics (T382)
Single LOS or Vector Winds?

- Important configuration issue for GWOS (impact vs. cost); ESA’s ADM/Aeolus wind mission has single Light-of-Sight (LOS).

- Experiments need to be performed with variable number of perspectives:
  - One; single line of sight, similar to ADM/Aeolus
  - Two; full horizontal wind vectors, left or right side of satellite track
  - Four; full GWOS coverage; wind vectors on both sides of satellite track
Four experiments, all verified against Nature Run

- **CTRL**: Observations as assimilated operationally by NCEP;
- **DWL1**: As CTRL with one-telescope DWL data added, single perspective (45°);
- **DWL2**: As CTRL with two-telescope DWL data added, two-perspective (45° and 315°);
- **DWL**: As CTRL with four-telescope DWL data added (four looks);

Cycling experiments with 6h assimilation window from July 01 to Aug 15, 2005

**EXP**: CTRL, DWL1, DWL2, DWL

Five-day forecast launched every day at 00Z
GWOS Lidar Wind obs

**Distribution of Lidar observations at 2005072100**

**Number of Lidar obs per analysis cycle (shown only for 00Z)**
Analysis Impact: Wind

RMSE: WIND P200 Global, Analysis against NR

Verification Date

a) CTRL 3.940 45
   DWL1 3.576 45
   DWL2 3.439 45
   DWL  3.266 45

RMSE: WIND P200 Tropic, Analysis against NR

Verification Date

b) CTRL 5.142 45
   DWL1 4.420 45
   DWL2 4.180 45
   DWL  3.779 45

RMSE: WIND P850 Global, Analysis against NR

Verification Date

c) CTRL 2.405 45
   DWL1 2.376 45
   DWL2 2.345 45
   DWL  2.318 45

RMSE: WIND P850 Tropic, Analysis against NR

Verification Date

d) CTRL 2.432 45
   DWL1 2.339 45
   DWL2 2.249 45
   DWL  2.137 45
Analysis Impact: Wind ...

(Tropical Wind RMSE)
Forecast: Tropical Wind
(RMSE at 200, 850hPa)
Forecast: Tropical Wind ...
(RMSE for the whole pressure levels)
Forecast: Tropical Temperature
(RMSE for the whole pressure levels)
Forecast Impact: Geopotential Height AC
(500 hPa AC coefficients)
Summary and conclusions

- The lack of vertically resolved wind observations continues to be a major shortcoming of the Global Observing System
  - Here shown in the context of a modern, satellite radiance based assimilation system
- A comprehensive OSSE system has been developed under the Joint OSSE collaboration
- Results simulating expected impact of GWOS observations on NCEP GFS system are very encouraging
  - Small positive impact in NH extratropics (summer)
  - Larger positive impact in SH extratropics (winter)
  - Large positive impact in tropics; hurricane relevance
  - Two perspectives, more coverage lead to larger impact
Plans for WLS OSSE

- Experiment in opposite season (NH winter/SH summer)
- Increased horizontal resolution (T-574 and higher; requires new Nature Run)
- Detailed case studies
- Separate assessments of the impacts of Direct Detection and Coherent Detection
- Other orbits, e.g. different altitude, lower inclination
- Impact on applications other than NWP
- Other OSSEs planned (e.g. DWSS; funding being negotiated with DoD)
Joint OSSE data set

Joint OSSE Nature run and Simulated Observations
Joint OSSE Nature Run by ECMWF
Spectral resolution: T511, Vertical levels: L91, 3 hourly dump

13 month long. Starting at 12Z May 1, 2005
Daily SST and ICE: provided by NCEP


Copies are available to designated users for research purposes & to users known to ECMWF
User list is maintained by Michiko Masutani (NOAA/NCEP)
contact: michiko.masutani@noaa.gov

Complete Nature Run data set is posted at NASA/NCCS portal
http://portal.nccs.nasa.gov/osse/index.pl
Password protected. Accounts are arranged by Ellen Salmon (Ellen.M.Salmon@NASA.gov)
Limited data set is available from NCAR
http://dss.ucar.edu/datasets/ds621.0/matrix.html
Contact: Chi-Fan Shih chifan@ucar.edu and Steven Worley worley@ucar.edu
Simulated radiance data,
Only Clear Sky radiance are posted
(Cloudy radiance are also simulated. Radiance with mask based on GSI usage is also simulated. But these data are not posted.)
BUFR format for entire Nature run period
Type of radiance data and location used for reanalysis from May 2005-May2006

Simulated using CRTM1.2.2
No observational error added

Conventional data
Entire Nature run Period
Restricted data removed
Cloud track wind is based on real observation location
No observational error added
Simulation of radiance data at NOAA
Jack Woollen and Michiko Masutani

Step 1. Thinning of radiance data based on real use

GOES and SBUV are simulated as they are missing from the GMAO dataset.

PrepBUFR is simulated based on CDAS distribution and quality controls.

Radiance data for instruments used in 2005-2006 are generated at the footprint used by the NCEP reanalysis.

Simulation was conducted using CRTM 1.2.2.

Some calibration and validation will be conducted by NCEP and NESDIS. However, users are expected to perform their own calibrations and validation.
Step 2. Simulation of radiance data using cloudy radiance

Cloudy radiance is still under development. The simulation of cloudy radiance was completed but may be repeated with a newer version of CRTM when it is ready.
**Nature Run**  
(grib1 reduced Gaussian)  
91 level 3-D data (12 Variables)  
2-D data (71 Variables)  
Climatological data

**Observation template**  
Geometry  
Location  
Mask

**Decoding grib1**  
Horizontal Interpolation

**DBL91**

- Need complete NR (3.5TB)  
- Random access to grib1 data  
- Need Data Experts

**Running Simulation program (RTM)**

- Need lots of cpu’s  
- Need Radiation Experts

**Post Processing (Add mask for channel, Packing to BUFR)**

**Simulated Radiance Data**

- Need Data Experts but this will be a small program
Evaluation of simulated GOES and AMSUA at the 1st step (12hr fcst) of the Nature Run simulated with 2005 template
Tong Zhu (NESDIS)

Fig. 1 NOAA -15 AMSU-A Channel 1 brightness temperature at GSI analysis time 0000 UTC May 2, 2005, time window 6 hours from (left) observation, (right) CRTM simulation with NR atmospheric profiles.

Observation and simulation of GOES-12 Sounder 18 IR channels at over North Atlantic region at 1200 UTC October 1, 2005.
Tong Zhu (NESDIS)

These figures are expected to be very similar. These figures do not have to be same as weathers are different, but similarities are observed.
The Nature run start at May 1st 12z. At 00z May 2\textsuperscript{nd} (12hr forecast), the Nature Run fields are still very close to real atmosphere and simulated radiance can be compared with real observations.
Data Distribution

**NASA/NCCS**

http://portal.nccs.nasa.gov/josse/index.pl

Contact:
Ellen Salmon  Ellen.M.Salmon@NASA.gov
Bill McHale  wmchale@nccs.nasa.gov

**NCAR**

Currently saved in HPSS  Data ID:  ds621.0

http://dss.ucar.edu/datasets/ds621.0/matrix.html

Contact:  Chi-Fan Shih  chifan@ucar.edu  and Steven Worley  worley@ucar.edu

Additional Data posted at Joint OSSE Home page http://
www.emc.ncep.noaa.gov/research/JointOSSEs/

[Simulation of TC vital]

TC vital was simulated using software originally written by Tim Marchock and currently developed by Guan Ping Lou of NCEP.

Software used for simulations are all posted. CRTM used for simulation. CRTM1.2.2 (Different from the version posted at JCSDA website)
Radiance data at NASA/NCCS

Simulated radiance data, with and without MASK in BUFR format for entire Nature run period.

Type of radiance data used for reanalysis from May 2005-May 2006.

Simulated using CRTM1.2.2

Path: /josse

File/Directory Size
NCEP-NESDIS 8.0K  go to dir

NCEP-NESDIS 8.0K  go to dir

SimRad.v4.201104 8.0K  go to dir

osbuvo_n_t511.v0905 8.0K  go to dir

prepoufr_n_t511.v0903 8.0K  go to dir

theoats_n_t511.db0l.v0009 8.0K  go to dir

File/Directory Size
NC2005.bfr 8.0K  go to dir

NC2005.mask.bfr 8.0K  go to dir
Joint OSSE Data set at NCAR

Currently saved in HPSS, Data ID: ds621.0
http://dss.ucar.edu/datasets/ds621.0/matrix.html

ECMWF Joint Observing System Simulation Experiment (OSSE) Nature Run

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<tr>
<th>Data Description</th>
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<td>All Data by Access Option</td>
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<td>NR2006 - T511NR 20050501-20060601 nature run to study data impact on large scale events</td>
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<tr>
<td>CLOUD - Cloud analysis from 200505-200606</td>
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<tr>
<td>T799NR - T799NR including T799Oct05 and T799Apr06</td>
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<tr>
<td>ObsRadiance - Observed radiance</td>
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<tr>
<td>SmuCirSkyRad - Simulated clear sky radiance</td>
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</tr>
<tr>
<td>Real.v1110 - real observations without restricted data in ncep prepbufr format</td>
<td>@</td>
</tr>
<tr>
<td>Simulated.v1110 - simulated observations in ncep prepbufr format</td>
<td>@</td>
</tr>
</tbody>
</table>

NCAR Contact:
Chi-Fan Shih              chifan@ucar.edu   Steven Worley              worley@ucar.edu
Hurricane Case study
Michiko Masutani

Investigate design for OSSE experiments.

Experiments comparison between model resolution and GWOS data to find out the best resolution for the WLS OSSE

Effect of observational error in data impact
Atlantic Hurricane in the nature run for the analysis period of 9/25-10/10

Simulated observation
Control data: Observation type and distribution used by reanalysis for 2005.
Observational error is not added to the control data but calibration was performed to demonstrate the impact of observational error in control data.

DWL data: GWOS concept DWL simulated by Simpson weather associates.

The figure produced by Joe Terry
Minimum Mean Sea level Pressure

The verification period:
Sep28-Oct13, 2005
in 72 hour forecast
Evaluated at 00Z only

This display indicates the hurricane track and intensity

Nature run
Truth
Minimum Mean Sea level Pressure
The verification period Sep28-Oct13, 2005
72 hour forecast evaluated at 00Z only

T170 with large obs error in radiance

Better radiance data help track and intensity forecast. DWL also will improve intensity forecast even with perfect radiance data.

T170 No obs error in radiance

T170 with large obs error in radiance

Add DWL

Add DWL

Improve radiance data

Improve radiance data

Add DWL
Impact of resolution vs. GWOS DWL

Improvement by Increasing resolution

- T126 → T170
- T170 → T254
- T254 → T382

Improvement by Adding GWOS DWL

- T126
- T170
- T254
- T382

Reduction of RMSE from NR in meridional wind
Zonal averaged
The verification period
Sep 28-Oct 13, 2005
in 72 hour forecast
Evaluated at 00Z only

Add large error to radiance data

More verification planned.
Add forecast from 12z. Try DWL with other configuration.
Produce hurricane track diagnostics.
OSSE with control observation without observational error is useful to provide initial outlook of data impact - a new type of observation.

Some interesting findings

- DWL improves both intensity and location of a hurricane at all resolution even with perfect control observation.
- In hurricane season, increasing model resolution will be more effective in large scale forecast. Improvement due to adding DWL is mainly over hurricane.
- Random error do not have significant impact in large scale, but more impact in smaller scale.
- With better radiance data impact of DWL was enhanced.
- At least T170 resolution is required to utilize DWL data for hurricane forecast. Impact of DWL is larger in T254 than in T170 model forecast. T382 model for OSSE with T511 Nature run may not be the best.
Further work on Hurricane Case study

◆ Add various observational errors to control observations and study data sensitivity to the data impact. This by itself is a major important project.

◆ Increase forecast frequency to 12 hour to get better statistics

◆ Produce standard EMC skill package and hurricane diagnostics for better comparison.

Acknowledgement

The nature runs for Joint OSSEs were produced by Dr. Erik Andersson of ECMWF. We appreciate GMAO to providing initial satellite data for calibration at ESRL. GMSO also provided code to add random error to simulated data and ESRL provided amplitude used for their experiments.
Beyond wind lidar OSSEs

- OSSEs for JPSS (JPO)
- OSSEs for DWSS (CAPE, OSD)
- GPSRO
- GOES-R