OBSERVING SYSTEM SIMULATION

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POTENTIAL IMPACT OF WINDSAT

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1. INTRODUCTION

In February 1983, a workshop was convened at NMC to consider the design of credible simulation experiments. There were representatives from many institutions in attendance; almost all had been involved previously in the conduct of data impact or simulation experiments. From their past experience the participants had developed a keen awareness of the magnitude of the resources required to conduct such work and of the difficulty of producing results which are widely accepted as authoritative.

The importance attached to the conduct of simulation experiments arises from the imperative necessity of providing input to programs for assessing the likely cost/benefit ratio of new global observing systems. Two such systems were specifically considered during the workshop. One systen consists of a new generation of satellite borne temperature sounders; the other is a polar orbiting satellite instrument capable of observing vertical profiles of the horizontal wind - WINDSAT.

The workshop participants arrived at a plan for cooperative conduct of an observing system simulation experiment designed to assess the potential impact of these new observing systems. Because the full investigation will require the expenditure of significant resources, the participants focused strongly on the question - How can the validity of the experimental design be made credible?

In this paper we present our understanding of the key methodology developed by the workshop participants in order to establish the credibility of the overall experiment. The specific work conducted at NMC in support of the effort is also detailed.

2. THE VALIDATION EXPERIMENT

In contrast to a study of the impact of real observations (e.g., Halem, et.al, 1982), an observing system simulation experiment requires the fabrication of simulated data. These are constructed by interpolating to the location of the idealized observations in a reference atmosphere, that has been produced by a numerical prediction model. Employing these simulated data one attempts to assess their potential impact on the accuracy of analyses and forecasts.

In spite of the effort expended to carry out an OSSE, it is simple to cast doubt upon the results. Recognizing this, the workshop sought a method by which to enhance the credibility of the OSSE. Since real data impact studies, previously carried out by several institutions, can be replicated within the framework of an OSSE, it was proposed that such an experiment could serve to calibrate, or validate, the realism of the OSSE techniques. Simply put, if the previously obtained results of real data impact studies can be reproduced in an idealized OSSE, then one may have more confidence in the results obtained when the experiment is performed with simulated, hypothetical data.

To replicate an actual data impact study using the mechanisms available for an OSSE necessitates the fabrication of a realistic reference atmosphere and of a realistic sample of observations. The reference atmosphere must be produced for the same season and synoptic regime as prevailed during the real-data study. That requirement may be satisfied by producing an extended forecast based on initial data taken from the period of the real-data study. The generation of realistic observations has two aspects. Determining the location, time and completeness of the simulated observations is easy, since these can be matched directly to their real counterparts. The specification of observational error is however a more difficult problem. The procedure adopted is outlined in the Section 3.

The impact on both analysis and forecast accuracy are often estimated in real, data impact studies. The simulation method to be employed in the validation experiment will have a potential problem in assessing analysis impact. Advanced data assimilation systems use statistical procedures that require estimates of both forecast and observational error. In the real-data environment these parameters are unknown; in the simulation experiment we are perforce aware of the relevant statistics. At least in principle, this knowledge ought to lead to an optimistic assessment of the skill of the full, simulated data set's impact on analysis accuracy. In turn, this may yield an underestimate of the impact of an observational sub-system's contribution.

The assessment of the simulated observing system's impact on forecast accuracy must also be treated cautiously, because the simulated reference atmosphere cannot possess the complexity of the real atmosphere. One may expect an imperfect observing system to perform better when sampling the reference atmosphere than it can when faced with the myriad of phenomena manifested by the real atmosphere. Conversely it is likely that the reference atmosphere may provide less opportunity for improvement when the observing system is augmented.

Table 1 - OBSERVATIONAL ERROR STANDARD DEVIATIONS

Surface Reports

SFCLT	SFCST	SFCBT	SFCLP	SCFSP	SFCBP	SFCLW	SFCSW	SFCBW
1.0	1.0	1.5	1.0	1.0	2.0	0.0	2.5	0.0

Upper Air Reports

Pressure	1000	850	700	500	400	300	250	200	150	100	70	50	30	20	10
RADT	1.1	1.1	1.1	1.3	1.5	1.7	1.9	2.0	2.1	2.2	2.5	3.0	3.5	4.1	4.5
DRPT	1.1	1.1	1.1	1.3	1.5	1.7	1.9	2.0	2.1	2.2	2.5	3.0	3.5	4.1	4.5
RADW	2.0	2.0	3.0	4.0	5.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
DRPW	2.0	2.0	3.0	4.0	5.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
PIBW	1.8	2.6	3.5	5.0	6.0	8.2	10.0	10.0	10.0	9.2	8.0	6.0	6.0	6.0	6.0
AIRT	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
ASDT	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
AIRW	7.0	7.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
ASDW	2.0	2.0	3.0	4.0	5.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
COBW	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
SATN	4.0	4.0	5.0	7.0	7.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
SATJ	6.0	6.0	6.0	10.0	10.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
SATE	7.0	7.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
SATI	4.0	4.0	5.0	7.0	7.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
SATT	4.0	4.0	5.0	7.0	7.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
SATF	7.0	7.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
SATG	7.0	7.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
TIROS Soundings and WINDSAT															
TIRAB	2.0	1.8	1.7	1.8	1.8	1.9	1.9	2.0	2.0	2.2	2.4	2.5	2.6	2.8	2.8
TIRC	3.9	2.5	2.2	2.2	2.0	1.9	1.8	1.7	1.6	1.4	2.5	2.6	2.7	2.8	2.8
WSAT	1.0	1.3	1.6	2.0	2.3	2.5	2.6	2.7	2.8	2.9	2.9	3.0	3.0	3.0	3.0

Legend:

SFCL - Surface land	AIR - Aircraft	T - temperature (in °K)
SFCS - Surface ship	ASD - ASDAT	W - wind (in ms^{-1})
SFCB - Surface buoy	COB - COBAL	P - Pressure (in mb)
RAD - Radiosonde	SAT - Satellite cloud tracked winds	TIRAB - TIROS A&B retrievals
DRP - Dropsonde	WSAT - WINDSAT	TIRC - TIROS C retrievals
PIB - PIBAL		

Table 2 - TIROS SYSTEMATIC TEMPERATURE ERRORS (°K)

Pressure Layer	Retrieval Method A	B	C
50-70	0.0	0.0	0.0
70-100	-0.7	-0.7	-0.5
100-150	-0.5	+0.15	-0.1
150-200	-0.1	+0.3	+0.4
200-250	+0.5	+0.6	+1.2
250-300	+0.6	+0.5	+0.9
300-400	+0.1	-0.05	-0.15
400-500	-0.4	-0.3	-1.1
500-700	-0.5	-0.35	-1.2
700-850	-0.5	+0.35	-0.6
850-1000	-0.35	+0.3	+1.65

Recognizing these uncertainties does not vitiate the basis for conducting the validation experiment. Its outcome should provide valuable information on the practical limits of OSSE's as tools for quantitative assessment of the potential of new observing systems.

3. GENERATION OF SIMULATED DATA

ECMWF provided NMC with a 20-day forecast produced with the N48, 15 level version of its grid point model for the period 0000GMT 10 November 1979 to 0000GMT 30 November 1979. This forecast was used as the reference atmosphere from which simulated observations were constructed by NMC. To determine which observations were to be simulated and the locations at which the observations were to be constructed, NMC employed the full list of FGGE level II b data for the period 0000GMT 9 November 1979 to 1800GMT 29 November 1979 which was also provided by ECMWF.

All types of FGGE data except two, LIMS and COBAL, were simulated. To do this, we first interpolated the appropriate reference atmosphere fields to the observation locations. The interpolation was biquadratic in the horizontal and linear with ln P in the vertical. No time interpolation was performed for any type of report, since all simulated observations valid within 3 hours of synoptic time (0000GMT, 0600GMT, 1200GMT, or 1800GMT) were assumed to apply at the synoptic time.

Appropriate random and systematic errors were added to the interpolated values. The random errors were generated by providing a random number generator with an observational error standard deviation appropriate for the type of instrument and the type and level of the observed variable. The observational error standard deviations are, for the most part, those used at ECMWF, given in Table 1. Only satellite temperature soundings were assumed to have systematic errors. The systematic errors used were taken from Schlatter (1982) as given in Table 2. Any observed values noted as missing in the FGGE data are also missing in the simulated data. Finally, the simulated observations were put into NMC format and written out.

In order to simulate data from the proposed WINDSAT instrument, we assumed the WINDSAT profiles were colocated with the satellite temperature soundings. The simulated WINDSAT data may have greater impact than if it were not colocated with the satellite temperature soundings.

The simulation of both satellite temperature soundings and WINDSAT data required knowledge of the cloud cover. For this purpose, we tuned a cloud algorithm developed by the USAF to the ECMWF forecast. The algorithm uses temperature and relative humidity information to provide both the cloud cover at individual levels and the integrated cloud amount down to the individual levels. We discussed this algorithm and its use with the ECMWF forecast with Hilding Sundquist during a recent visit to NMC. Sundquist felt that the cloud cover we produced in this manner was similar to what would be produced by the ECMWF algorithm, and would be adequate for our purpose.

We used the total integrated cloud cover to assign a retrieval type to each satellite temperature sounding in the following manner:

0% - 60%	Path A retrieval
61% - 90%	Path B retrieval
91% - 100%	Path C retrieval

These values were chosen because they closely replicated the actual numbers of Path A, B, and C retrievals in the FGGE Level IIb data at day 1 of the forecast (0000GMT, 10 November 1983).

The integrated cloud amounts, down to the individual levels, were used to determine the level at which WINDSAT data would cease to be available. When the integrated cloud cover exceeded 90%, we assumed that WINDSAT data was no longer available. Furthermore, it was assumed that the WINDSAT instrument would see through ice clouds, therefore, we only checked for cloud cover at and below 500mb in creating the WINDSAT data.

Thus, both simulated FGGE Level IIb data and simulated WINDSAT data is available in NMC format for the period 0000GMT 10 November 1979 - 1800GMT, 29 November 1979. This data was subsequently converted to FGGE Level IIb format by GLAS.

5. ACKNOWLEDGMENTS

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6. REFERENCES

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