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STATUS AND RESULTS OF OSEs

Data Impact Studies using the new Global Assimilation System of the Canadian Meteorological Centre

(Submitted by Mr Jean Pailleux, Rapporteur on OSEs and OSSEs)

Summary and Purpose of Document

The document summarizes major results of the assimilation and forecast experiments on the impact of different observing configurations including ATOVS radiances, cloud drift winds, humidity estimates from satellites, aircraft, radiosondes, surface and marine observations.

ACTION PROPOSED

The meeting is invited to take into consideration the information contained in this document when discussing status and results of OSEs.

P1.2

DATA IMPACT STUDIES USING THE NEW GLOBAL ASSIMILATION SYSTEM OF THE CANADIAN METEOROLOGICAL CENTRE

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1. INTRODUCTION

Observing-system experiments (OSEs) play a role in the evaluation of the data assimilation and the Numerical Weather Prediction systems. An understanding of the relative utility of current observing systems to NWP is also important to help make effective use of resources for observations.

The set of OSEs presented here was run using the 3D-Variational (3D-Var) data assimilation system described in Gauthier et al. 1999. In June 2000, the 3D-Var system was updated to produce analyses directly on the model's vertical and horizontal grid (Chouinard et al. 2001), and in September 2000 the System was further updated to the direct assimilation of satellite radiances in replacement of so-calles satellite temperature retrievals (SATEM) (Chouinard et al. 2002). The latest version of the 3D-Var analysis program was implemented in December 2001 with a number of modifications that improved the quality of the Canadian Meteorological Centre (CMC) global forecast system. The 3D-Var analysis program was modified to assimilate temperature and surface pressure instead of the geopotential heights. The number of assimilated levels was increased from the 16 mandatory pressure levels to 27 levels. Also, aircraft temperature reports and AMSU-A channels 3, 4 and 5 were added to the assimilated observations. The quality control of observations, previously based on the method of optimum interpolation, was changed to a combination of a background check prior to the analysis and a variational quality control during the minimization (Andersson et al. 1999).

The purpose of this study is to verify the impact of various observation data types in the modified CMC 3D-Var global analysis. The data selection is summarized in the following section.

The impact is assessed in both winter (from 17 December 2001 to 27 January 2002) and summer (from 15 June to 31 July 2002) on a total of six weeks per period, with 6-day forecasts done at 12-hour interval. Results from the winter period are presented here; the summer period should be ready by the time of the symposium.

The results are grouped in three series of OSEs for satellite, conventional and aircraft observations over the following areas: Northern Hemisphere, Southern Hemisphere, Tropics and North America.

2. EXPERIMENTS

Assimilation and forecast experiments have been performed in order to investigate the impact of different observation configurations. The observing systems tested were ATOVS radiances, cloud drifts or water vapor atmospheric motion winds (AMW), humidity estimates from satellite (HUMSAT), aircraft, radiosondes and surface observations. In this study, the control run is the CMC operational 3D-Var assimilation system. The use of different observing systems was evaluated over the data-rich (North America and Northern Hemisphere) and the data-poor (Tropics and Southern Hemisphere) areas. The method of evaluation used to measure the impact is by comparing analyses and forecasts to a global set of quality controlled radiosonde observations.

Each experiment is identified according to the following nomenclature:

CNTRL the winter reference, it is the control done with CMC global operational assimilation and forecast system.

NOTO the control observations minus the ATOVS radiances, AMSU-A channels 3 to 10 from NOAA-15 and NOAA-16.

NOSW the control observations minus the AMWs from GOES-8&10, METEOSAT-5&7 and GMS-5.

NOHU the control observations minus HUMSAT humidity data.

NOSAT the control observations minus all satellite data, i.e. ATOVS, AMWs and HUMSAT.

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NOUA the control observations minus all radiosonde data, including TEMP, PILOT and dropsondes observations.

NOAI the control observations minus all aircraft data (wind and temperature), including AIREP, ACARS and AMDAR observations.

AITT the control observations minus all aircraft temperature data.

AIUV the control observations minus all aircraft wind data.

NOSF the control observations minus all surface observations, including SYNOP, SHIP, DRIFTER and BUOYS, but the surface level from radiosonde stations still included.

In the following sections we examine the differences between the control and all experiments for several pressure levels and meteorological variables

3. IMPACT OF THE OBSERVING SYSTEMS

3.1 *Satellite Observing Systems*

The impact of satellite data can be assessed by comparing the CNTRL, NOTO, NOSW, NOHU and NOSAT experiments. The results are evaluated using the RMS forecast impact (FI) (Zapotochy et al. 2002). The FI of an individual data type is evaluated as the RMS error of the denied forecast minus the RMS error of the control forecast, this difference is divided by the RMS error of the control forecast and multiplied by 100 to normalize the result. It provides a percentage improvement with respect to the control forecast. A positive FI value means that the forecast quality is improved when the data type is included.

Figure 1 illustrates the FI for the 500 hPa geopotential heights at the following forecast periods (24, 48, 96 and 144 hours) over the four geographical areas. The results show a large positive impact of the satellite data experiment, NOSAT, in the Southern Hemisphere and Tropics and a smaller positive impact over the Northern Hemisphere. The positive impact of ATOVS data alone is more important in the extratropics especially for the Southern Hemisphere. In the Tropics, where the relation between heights and wind is weaker, the AMWs have a large positive impact on the wind vector quality. Note that the impact of withholding all satellite data types (NOSAT) is larger than the impact obtained with the denial of a single data type (NOTO, NOSW and NOHU) and clearly different from the their sum, especially in the Tropics and Southern Hemisphere. This results may be related to the interactions between ATOVS and AMWs data.

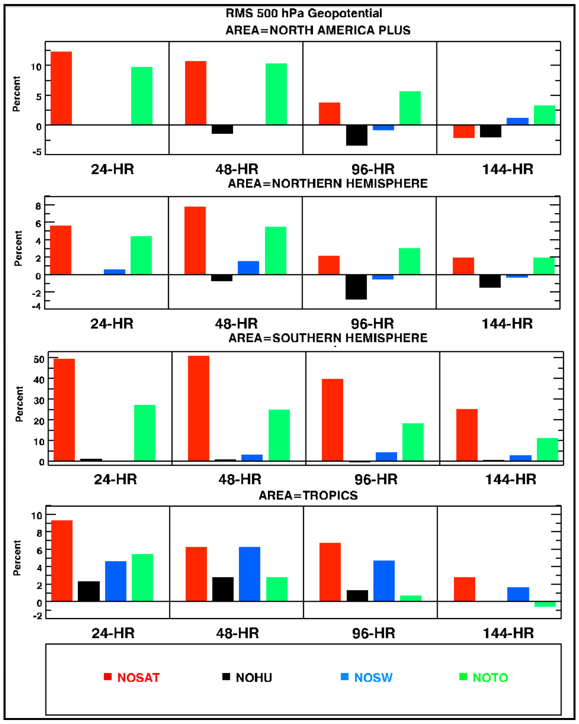


Figure 1. Forecast impact (%) for 500 hPa GZ of the satellite data experiments (NOSAT, NOHU, NOSW, NOTO), forecast periods: 24, 48, 96 and 144 hours.

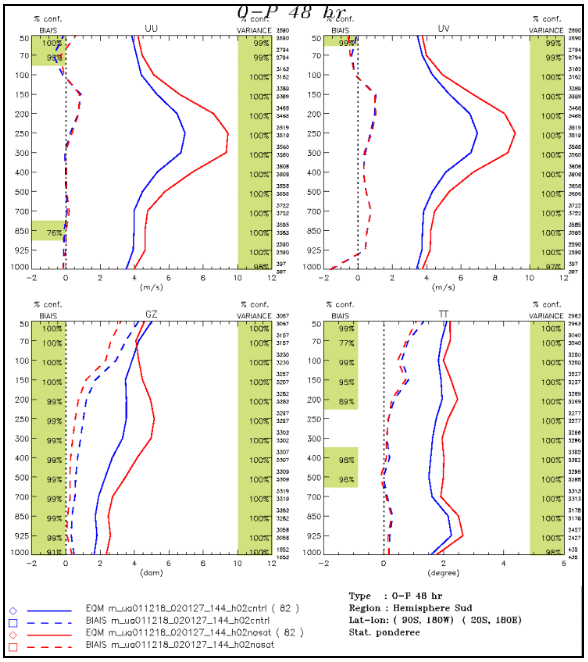


Figure 2. RMS (full) and BIAS (dashed line) errors against the Southern Hemisphere radiosonde observations for the 48h forecasts. The blue lines are for CNTRL and the red lines for the NOSAT experiment. Highlighted % values are statistical significance test results.

The use of satellite data provides a large improvement to the quality of all forecast variables. Figure 2 compares the results of CNTRL and NOSAT experiments for the 48h forecasts. It shows the RMS and BIAS differences for temperature (TT), wind components (UU, VV) and geopotential (GZ), evaluated at standard pressure levels against the radiosondes of the Southern Hemisphere

All variables are improved by the inclusion of the satellite observations, for most of the troposphere especially in the layer 700-200 hPa.

3.2 *Conventional observing systems*

The evaluation of the impact of conventional data can be done with a comparison of CNTRL, NOUA, NOAI, NOSF and NOSAT experiments results. Figure 3 shows the FI on the 500 hPa geopotential heights at various forecast periods over the four geographical areas.

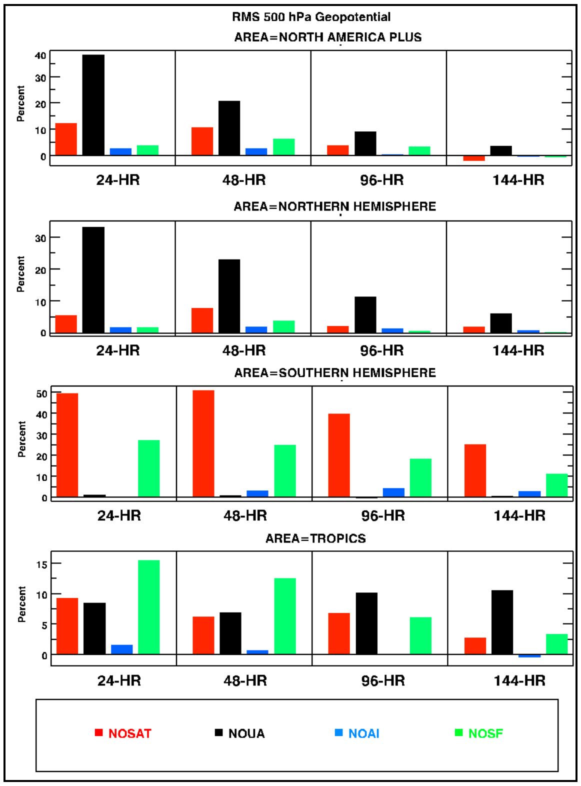


Figure 3. Forecast impact (%) for 500 hPa GZ of the 4 data types (NOSAT, NOUA, NOAI, NOSF) forecast periods: 24, 48, 96 and 144 hours.

Not surprisingly, the results demonstrate that for North America and the Northern Hemisphere, a large forecast impact is obtained from radiosonde observations (NOUA experiment) relatively to other observing systems. In the Southern Hemisphere the satellite data (NOSAT) have a forecast impact much larger than the radiosondes, while in the Tropics, the impact of the surface data (NOSF) on GZ is larger than the impact of radiosonde and satellite data.

Figure 4 shows the FI on the 250 hPa winds. The satellite data, altogether, provide the largest positive FI on 250 hPa winds over Southern Hemisphere and the Tropics. Over the Northern Hemisphere, the radiosonde observations are major contributors.

The use of aircraft data provides an important improvement but mainly for the short term forecast in North America and the Northern Hemisphere. Actually over North America, for the 250 hPa wind components, the FI values go from about 11% at 6-hr to ~2% at 24-hr for the no aircraft observations experiment (NOAI) (not shown). While for satellite data (NOSAT) the impact is larger at 24-hr.

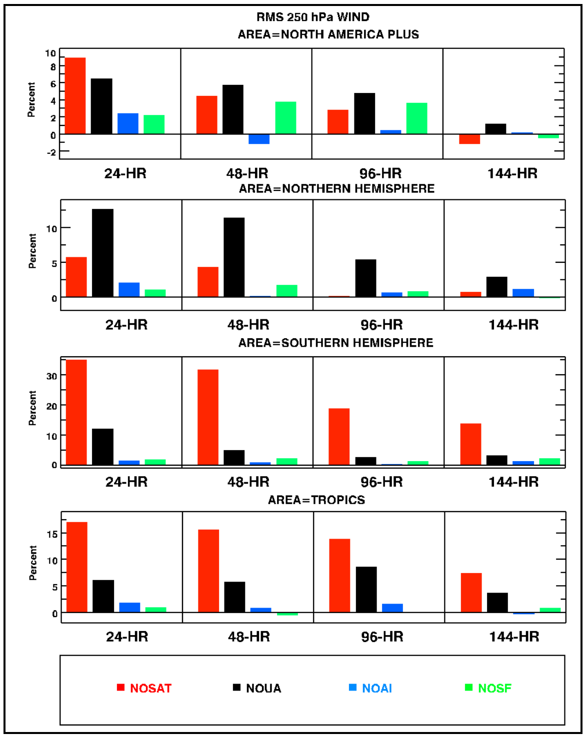
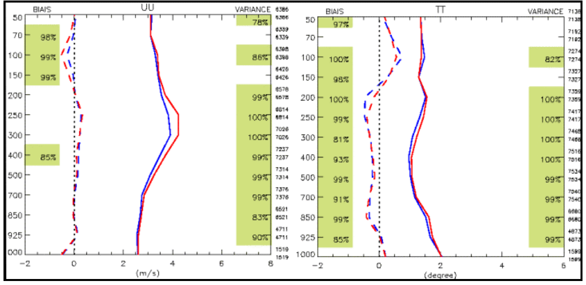


Figure 4. Forecast impact (%) for 250 hPa wind speed of: NOSAT, NOUA, NOAI and NOSF, and forecast periods: 24, 48, 96 and 144 hours.

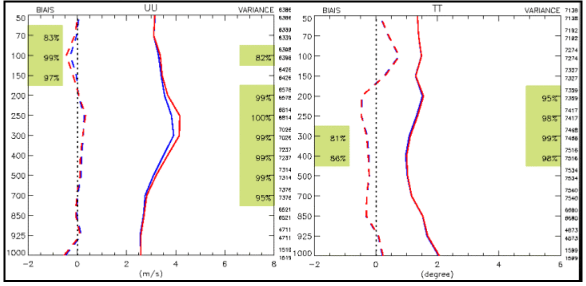
3.3 *Aircraft Observing Systems*

The impact of the wind and temperature variables of the aircraft observations can be examined separately with a comparison of CNTRL, NOAI, AITT and AIUV experiments. Figure 5 shows the 6-hr forecast verification results over North America at standard pressure levels. The use of all aircraft data, wind and temperature, has a positive impact on the short range forecast quality. The deterioration of the RMS error is more important with the denial of wind observations than it is for the temperature observations.

a) NOAI experiment



b) AIUV experiment



c) AITT experiment

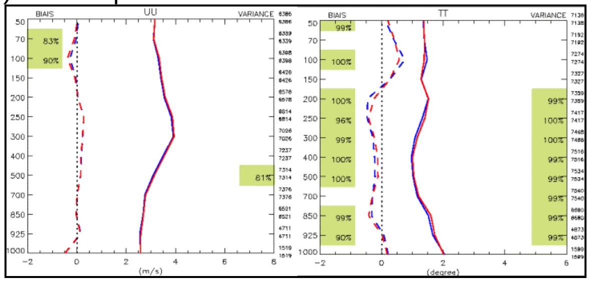


Figure 5. RMS (full) and BIAS (dashed line) errors against the North America radiosonde observations at 6h for the wind component (UU) and the temperature (TT). The blue lines are for CNTRL and red lines for aircraft experiments: (a) NOAI (b) AIUV, (c) AITT. Highlighted % values are statistical significance test results.

4. SUMMARY

The results of the OSEs indicate that, the use of all the considered observing systems is beneficial to various degrees to the quality of the new CMC 3D-Var global analysis. It demonstrates that over areas poor in conventional observations, satellite data clearly dominate and are the main contributor to the forecast performance. Over data rich areas the conventional data still provide the largest impact among the observing systems. The blend of observations from the various observing platforms: radiosonde, satellite, aircraft, various surface stations, etc. provides a more or less balanced analysis to the NWP system. The impact of the observing systems varies with the forecast projection time, the geographical area and the levels in the atmosphere.

Another noteworthy observation is that in the current CMC system, the impact of the data seems to generally diminish with the increase in forecast time. This is different form the results obtained at other weather centres and could indicate a growth of the forecast errors that is more rapid then is should be.

Additional verifications are being done using evaluation against analyses instead of observations. This is particularly important for the evaluation in regions with a poor density and distribution of radiosondes.

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