P1.8 **MONITORING AND ASSIMILATION IMPACT STUDY OF MOISTURE DATA FROM AIRCRAFT AT THE CANADIAN METEOROLOGICAL CENTRE**

Iriola Mati *, Réal Sarrazin, Yulia Zaitseva and Gilles Verner
Meteorological Service of Canada, Dorval, Quebec , Canada

1. INTRODUCTION

This work is sponsored by the Government of Canada through the CCG Search and Rescue New Initiative Funds (SAR NIF).

The goal is to develop and test a capacity for the Canadian Meteorological center (CMC) to assimilate aircraft moisture data into the Numerical Weather Prediction (NWP) models. And therefore improve the accuracy of MSC forecast of high–impact weather by adding humidity measurements from aircraft to the variety of data types assimilated into CMC NWP systems.

Sources of moisture information at CMC are limited to radiosonde, synop and satellite data. Thus, there is a lack of humidity data in the lower troposphere where weather and human activity take place. Fleming (Fleming at al. 2004) stated that there is a variety of reasons to increase the accuracy of humidity data at upper air. Amongst them they distinguish two important reasons: 1) the uncertainty over the timing and intensity of global warming due to anthropogenic causes and 2) the prediction of air quality.

CMC currently receives two types of aircraft reports that include humidity observations.

About 80 aircraft from Great Lakes Fleet Experiment (GLFE) are equipped with Tropospheric Airborne Meteorological Data Reporting (TAMDAR) instruments measuring moisture. The humidity observations are included in the BUFR reports obtained from AirDat (AIRDAT, 2004) by ftp server in the form of a relative humidity variable measuring at relatively low levels.

About 25 B757 jet aircraft from UPS AMDAR fleet (WVSSII-US) and 3 European (WVSSII-EU) aircraft equipped with second generation Water Vapor Sensing System-WVSSII (Fleming et al. 2004) that measure mixing ratio at upper, mid and low levels. Figure 1 shows the distribution data from aircraft with TAMDAR and WVSS instruments.

**Corresponding author address:*
I.Mati, Canadian Meteorological Centre, 2121 Trans-Canada Highway, Dorval, Québec, Canada, H9P1J3, e-mail: iriola.mati@ec.gc.ca

The concentration of TAMDAR data (shown by green) is mostly in the United States, around the Great lakes, Northern Plains and Ohio Valley, for WVSSII-US the concentration of data (shown by blue) is in the United States and in the central part of America, whereas for WVSSII-EU the concentration is mostly in Europe (shown by red).

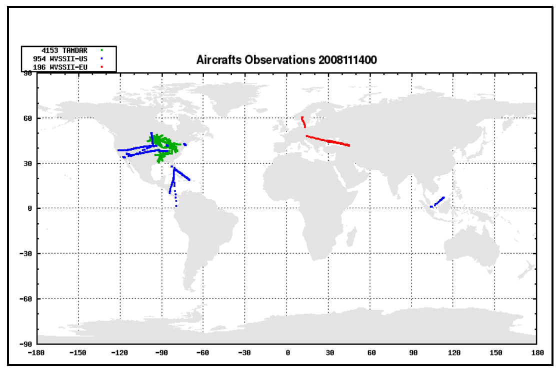

Figure 1. TAMDAR and WVSSII observations decoded by CMC over a 6-hour window centered at 00 UTC on 14 November 2008.

The monitoring and quality control of humidity data from aircraft are summarized in the following section. The set of observing system experiments has been done to measure the impact of GLFE TAMDAR and WVSSII moisture data in regional and global CMC analysis. The impact has been assessed in both winter and summer periods.

2. PROCESSNG AND MONITORING OF AIRCRAFT MOISTURE DATA AT THE CMC

The work for monitoring of aircraft humidity data was based in a previous experiment from Zaitseva et al. 2006. They developed the monitoring of aircraft with TAMDAR instruments for winds and temperature variables which presently are assimilated in the CMC operational NWP system.

The necessary adjustments to the decoding program of aircraft reports have been made to include the humidity observations with their quality indicators along with the temperature and the wind; the value of dew point depression (ES) computed from either the relative humidity (GLFFE TAMDAR aircraft) or the mixing ratio (WVSSII aircraft), is added to each report and saved in the database for further processing. The 3D-Variational (3DVar) analysis program (Gauthier at al. 1999) was modified to compute the observations minus first guess value (O-P) which is one the standard comparison made to evaluate the quality of the data. The 3dVar output files also include as a diagnostic, the O-P of the logarithm of the specific humidity value (lnQ).

The quality of humidity data from aircraft was monitored since January 2007. A number of programs have been prepared for the evaluation of aircraft reports and the results can be seen on the CMC web site. (http://collaboration.cmc.ec.gc.ca/cmc/data_monitoring/SAR/). This web site includes information about the number of TAMDAR and WVSSII observations, their distribution and time series of the mean and standard deviation of O-P temperature, wind, dew point depression and specific humidity values. One can also find information about monthly O-P statistics for individual aircraft with a list of aircraft with suspect and non-suspect observations, as well as statistics done by phase of flight for wind, temperature and dew point depression variables.

Figure 2 is an example of time series O-P statistics for a 25 day period for GLFE TAMDAR moisture data.

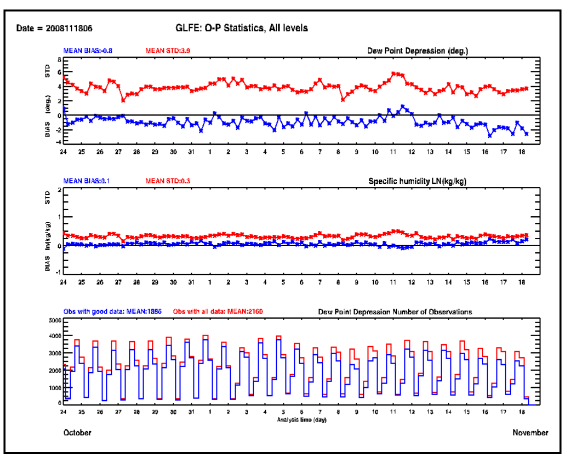

Figure 2. O-P statistics for the dew point depression GLFE TAMDAR observations in October-November 2008.

The evaluation of GLFE TAMDAR moisture data shows very good results, a negative dew depression bias of -0.8 deg. has been observed when considering all reports. Note that the quality of these data is better for low 701-1050 hPa (not shown here), than for high level, 301-700 hPa.

The monitoring results of moisture data reporting by the aircraft with WVSSII sensor showed higher mean bias and standard deviation in comparison with aircraft that use TAMDAR instruments until October 2007. After this period, the WVSSII-US aircraft reported data of humidity with less bias and standard deviation due to the improvements they made in data processing. WVSSII-EU aircraft have positive bias of dew point depression, which means the values of dew point depression are higher than those of CMC first guess. Thus, the instruments of European aircraft report dry values of relative humidity (variable measured by the instruments of those aircraft). The positive bias for WVSS-EU instruments found in our study is consistent with the results of another group in Europe using the numerical model COSMO-EU and the WVSS-II output (A.Hoff, 2008).

Figure 3 shows the evaluation of dew point depression for all TAMDAR, WVSSII-US and WVSSII-EU data from January 2007 to September 2008. The top graphic presents monthly evaluation of ES bias and bottom graph presents ES standard deviation. The results clearly indicate the good quality of moisture data for both TAMDAR and WVSSII-US instruments after October 2007.

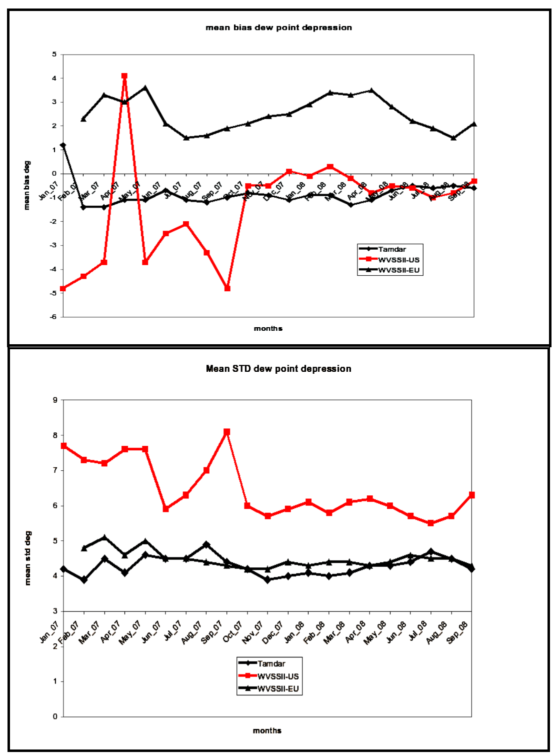

Figure 3. The time series of monthly mean statistics from Jan 2007 to Oct 2008 respectively for all TAMDAR, WVSS-US and WVSS-EU humidity data.

3. ASSIMILATION EXPERIMENTS

Several assimilation experiments were conducted to evaluate the impact of aircraft moisture data in the CMC regional and global NWP systems. The method of evaluation used to measure the impact is by comparing analyses and forecasts to a global and regional set of quality controlled radiosonde observations.

3.1 Regional assimilation cycles

The work for the assimilation experiments for dew point depression variable for regional assimilation cycles is carried out by using the CMC's system of Operational run Control Manager (OCM).

A regional assimilation cycle is initialized from the global GEM analysis with a 33km resolution. Each global analysis is valid 6 hours before the case hour in order to generate the regional trial field needed for the background check and analysis. Then, the regional analysis is used to start a 48 hours forecast of the regional GEM model with 15km resolution. The control is from a 6 hours regional data assimilation and forecast system and the analysis procedure is 3D-Var FGAT (First Guess at Appropriate Time).

For summer period (42 cases from July 6 to September 10 2007, for 00 and 12 UTC cases), the two experiments consisted in modifying the operational observations valid at case hour by including TAMDAR instrument observations with humidity, however in second one we used a lower (5deg.) observation error than in first experiment (6deg.) For the control run, we use OCM to generate the forecast fields starting from the operational observations. The results show a slightly positive impact of TAMDAR instrument data on average over Great Lakes region (not shown here), however the differences between the control cycle and experiments are small. It is also important to note that the impact of moisture data with lower observation error is more significant than with higher observation error. Thus, we decided to continue the assimilation experiments using the lower observation error (5deg.).

Since the monitoring results show that aircraft with WVSSII have significant improvements from October 2007 the data from these aircraft were included in the winter assimilation experiments. Two experiments were run from December 6 2007 to February 17 2008 (47 cases 00 and 12 UTC cases). The first experiment consisted in modifying the operational observations by including TAMDAR humidity data with blacklisting GLFE aircraft that were suspect during this period. The second experiment was run by including the humidity data from both GLFE and WVSSII aircraft in operational observations with blacklisting the aircraft having suspect value for the analyzing period. For the control run, we use OCM to generate the forecast fields starting from the operational observations.

In winter case, the results show that the use of humidity data from both TAMDAR and WVSSII instruments provides a slight improvement for forecast in Great Lakes region.

Figure 4 illustrates the precipitation scores for winter cases for shef network over North America.

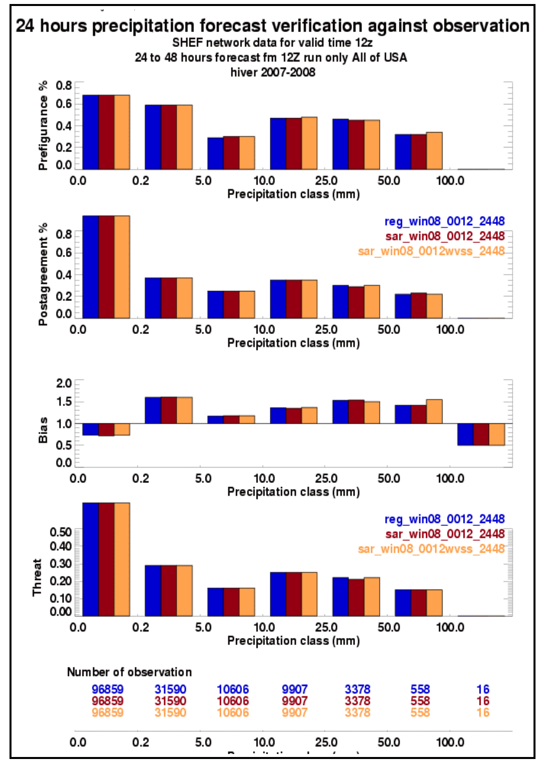

Figure 4. Precipitation scores for shef network for winter cases. Control in blue and experiments in red (TAMDAR) and orange (TAMDAR+WVSS).

An evaluation of the precipitation scores at shef and synopic network shows a slight improvement using both TAMDAR and WVSSII data for classes of precipitation between 25 and 50mm (there is less bias or a bit higher threat score compared to control (blue) and experiment1 (red)). We should point out that the differences between the experiments and the control are small at 48 hours forecast.

The experiment for winter period was repeated using 06 and 18 UTC cases. The experimental setup is the same as with 00 and 12 UTC cases. Thus, we verify 06, 18, 30 and 42 forecast hours instead of 12, 24, 36 and 48. The results show that the differences between the control run and experiments are very small. The differences are more obvious at 06hour than at 42hour forecasts.

3.1 Global assimilation cycles

The experiment was run using the 4D-Variational data assimilated system described in Laroche et al. 2005. The impact of aircraft moisture data is assessed in summer period (from 5 June to 31 August 2008) with 10-day forecasts twice a day at 00 and 12 UTC, using two configurations:
1) control experiment done with CMC global operational and forecast system;
2) humidity experiment included control plus humidity data from TAMDAR and WVSSII instruments, with blacklisting suspect aircraft for this period.

The results were evaluated using verification against radiosonde observations as well as against control analysis. The verification scores demonstrate however rather neutral impact of humidity aircraft data over analyzing areas (North America and Great Lakes region). It is important to note that this impact is not negative.

4. SUMMARY

This study clearly indicate the importance of aircraft moisture data in the CMC regional and global forecast system. The results of monitoring confirm that humidity data from both AMDAR and WVSSII-US instruments are good quality. WVSSII-EU instruments have positive bias of dew point depression which is an indication that these instruments can still improve.

We performed several assimilation experiments for summer and winter cases for regional and global cycles for both TAMDAR and WVSSII instruments. The assimilation of aircraft humidity data was successful. The verification and the precipitation scores showed that there is a slight advantage when using humidity data from both types of aircrafts. Based in the results of this study we will propose operational data of humidity from aircrafts.

5. ACKNOWLEDGMENTS

We would like to acknowledge the financial support of the Government of Canada for this initiative through the CCG Search and Rescue NEW Initiatives Funds and AirDat company for providing TAMDAR data.

6. REFERENCES

AIRDAT, 2004: TAMDAR observation quality assurance and BUFR format, version 1.5.2. [*Available from AIRDAT*, www.airdat.com]

Fleming, R. J. and R. D. May, 2004: The 2nd generation water vapor sensing system and benefits of its use on commercial aircraft for air carriers and society. Available for download at http://www.eol.ucar.edu/projects/wvss/spectrasensors.pdf

Gautier, P., C.Charette, L.Filion, P.Koklas and S.Laroche, 1999: Implantation of a 3D variational analysis at the Canadian Meteorological Centre. Part I: The Global analysis. *Atmosphere-ocean,* **37**,103-156.

Hoff A., 2008: Humidity measurements by Aircraft of the E-AMDAR Fleet. Available for download at: http://www.wmo.ch/pages/prog/www/IMOP/publications/IOM-96_TECO-2008/2(17)_Hoff_Germany.pdf

Laroche, S., P.Gautier, M.Tanguay, S.Pellerin and J.Morneau, 2005: Evaluation of the operational 4D-Var at the Meteorological Service of Canada. Preprints, *21th Conf. on Whether Analysis and Forecasting/16th Conf. on Numerical Weather Prediction,* Washington, Amer.Meteor.Soc., CD-ROM, 14B.3

Zaitseva, Y., G. Verner and R. Sarrazin, 2006: Monitoring of GLFE TAMDAR at the Canadian Meteorological Centre. Preprints,*10th Symposium on Integrated Observing and Assimilation Systems for Atmosphere, Oceans and Land Surface (IOAS-AOLS), Atlanta, GA, Amer. Meteor.Soc.,* CD-ROM, P2.7.