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PROJECTS, PLANNING AND WORK PROGRAMME

Development and Maintenance of the Aircraft Observing System QMS

Impact of AMDAR data in NWP Forecasts

(Submitted by Ralph Petersen)

SUMMARY AND PURPOSE OF DOCUMENT

Provides a progress and activity report for the United States AMDAR Programme regarding the impact of AMDAR observations on global Numerical Weather Prediction models.

INFORMATION ITEM

1. The Panel is invited to note the information contained in the document.

<u>Background:</u> For several decades, the World Meteorological Organization (WMO) has been sponsoring a series of scientific meetings to understand and assess the impact of various observing systems on Numerical Weather Prediction (NWP). The latest meeting was held in Sedona, Arizona in May 2012. Participants included representative of all major global and regional Data Assimilation (DA) and NWP centers, as well as experts in various observation systems and forecast applications. This paper presents a summary of the findings of this and previous workshops on the use and impact of AMDAR data on global scales.

<u>Results of earlier evaluations:</u> Before reviewing recent findings, results of work by Kelly et al. (2004), and expanded by Petersen (2004), are presented as background. These tests followed focused AMDAR evaluations by Andersson et al. (2005). The tests by Kelly et al. were conducted by first running the European Centre for Medium Range Weather Forecasts (ECMWF) global analysis and forecast systems using all data sources and then repeatedly rerunning the systems with one type of data being removed (e.g., with all data expect AMDAR temperatures and winds). The skill of the various "data denial" tests where then compared with that of the forecasts using all data to determine a measure of the impact of each data source using the formula:

$$(\text{ERROR}_{\text{(with AMDAR data)}} - \text{ERROR}_{\text{(without AMDAR data)}}) / \text{ERROR}_{\text{(without AMDAR data)}} .$$

The impact of AMDAR temperature (left) and wind (right) data on 12 to 48 hours forecasts for the entire global and the more-data rich North American areas are shown in figures 1 and 2.

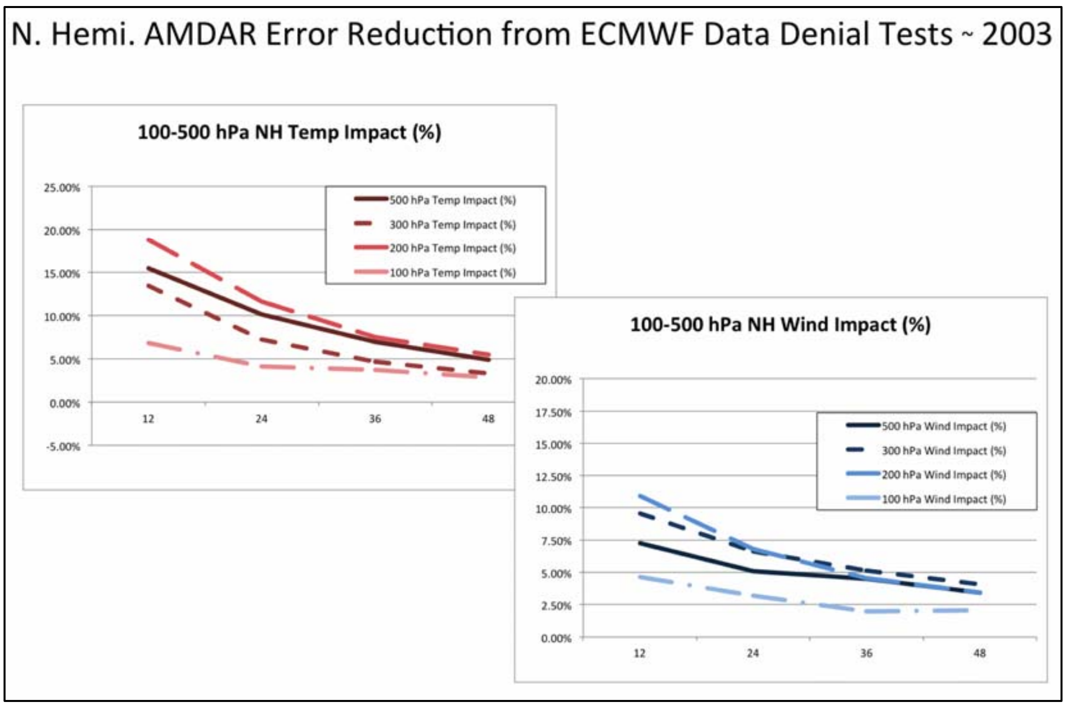

Figure 1: Impact of AMDAR Temperature (left) and Wind(right) observations on 12, 24 36 and 48 hour forecasts at 500, 300, 200 and 100 hPa in the Northern Hemisphere. Data provided by ECMWF.

Results for the Northern Hemisphere, where much of the data coverage was only at flight level (e.g., over ocean areas), showed that AMDAR observations:

1. Had their largest impact during the first day of the forecasts, reducing 12-hour temperature forecasts in the upper troposphere by 15-20%,

2. Had their largest impact in the upper troposphere (e.g., greatest at 200 and 300 hPa, but with notable impact at 500 hPa),
3. Generally had greater influence on temperature forecasts than wind forecasts, and
4. Had positive impact on forecasts out to 48 hours.

Results for the North American area, where the AMDAR data were more dense and available both at flight levels and from ascents/descents, showed that AMDAR observations:

1. Had their larger impacts during the first day of the forecasts, reducing 12-hour temperature forecasts in the upper troposphere by more than 20% and improving wind forecasts by nearly 15%,
2. Had their largest impact in the upper troposphere, with negligible impact at 100 hPa),
3. Had greater influence on temperature forecasts than wind forecasts, and
4. Had greater positive impact on forecasts out to 48 hours than for the global forecasts.

The impact of AMDAR data over other portions of the global is shown in Fig. 2, which compares wind forecast errors at four levels (500, 300, 200 and 100mb – corresponding to FL180, FL300, FL390 and FL 500) and four forecast lengths (12, 24, 36 and 48hrs). The figure not only reaffirms the finding previous findings but also shows that, even thought the majority of AMDAR available at the time of this study were concentrated over the United State, Europe, and Northern Hemispheric oceanic fight paths, AMDAR data benefitted NWP forecasts throughout the world, including the tropics and the Southern Hemisphere. In all but one instance, the forecasts use of aircraft data improved the wind forecasts. On average, forecasts for the Northern Hemisphere are improved by more than 0.5 knots at FL300-FL390. From the North Pacific, across North America and the North Atlantic and into Europe, improvements ranging from .6 to nearly 1 knot are typical for the 4 month averaged statistics. For individual cases, the improvements can be many times larger than this – often exceeding 10 knots. Smaller improvement is shown in the Southern Hemisphere, where fewer aircraft data are available. In the tropics, the improvements are surprisingly large, with the greatest impact (4 month average improvements nearing 1 knot) in Arabia, Indonesia and the Central Pacific (not shown). The degree of improvement decreased with forecast length, with reductions of from 25 to 75% shown at different levels and locations. Similar improvements and trends were also noted in temperature forecasts for these same levels for each region.

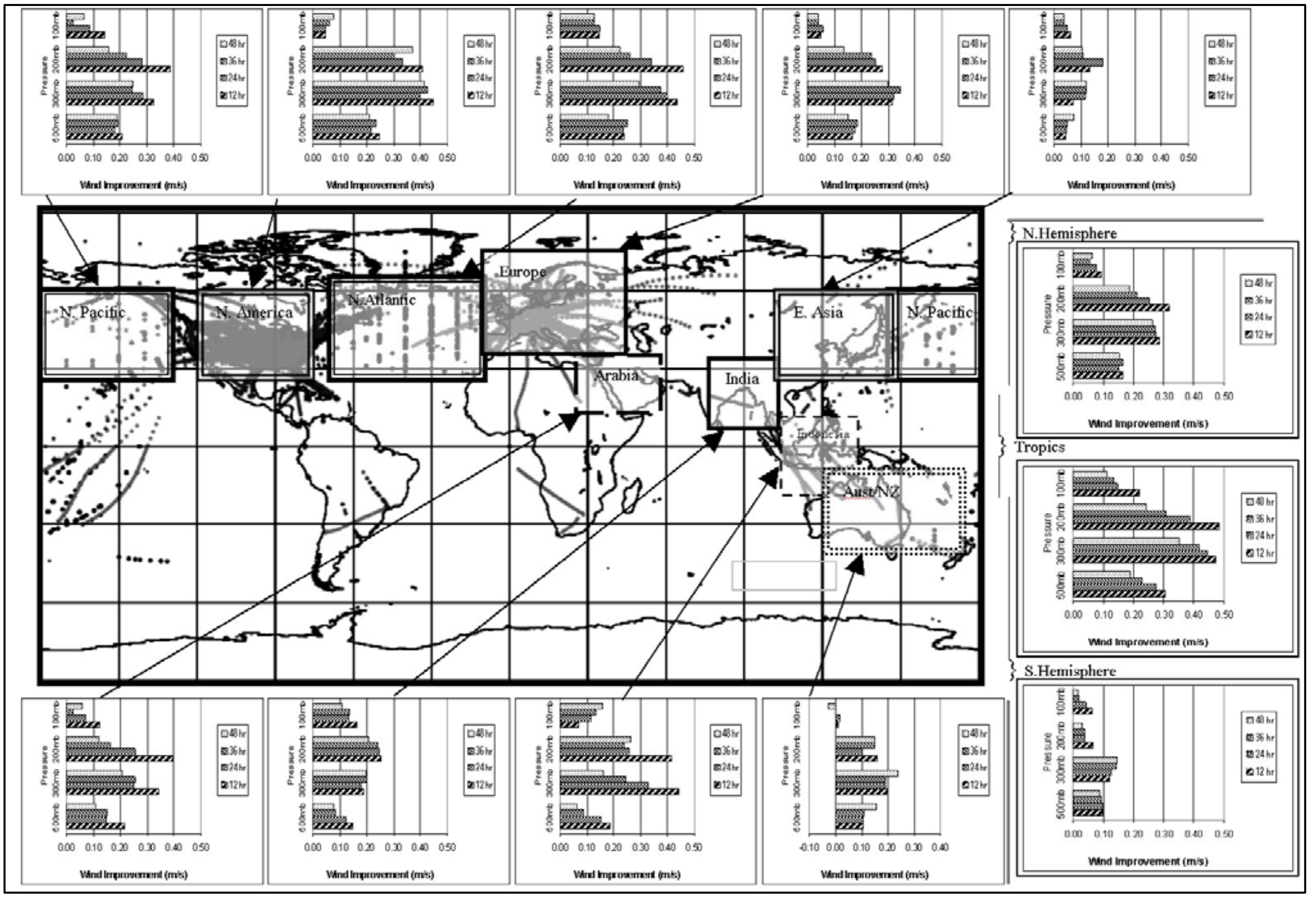

Figure 2: Improvement in Vector Wind Errors (m/s) at 500, 300, 200 and 100 hPa and 12, 24,36 and 48 hour ECMWF forecasts. Verification areas shown on plot of typical 6-hr aircraft data distribution at time of study. Figure taken from Petersen (2004).

<u>Recent tests of the impact of AMDAR observations on Global Forecasts:</u> During the past several years, alternative techniques have been developed to better understand and assess the relative impact of various observing systems to one other using more sophisticated DA systems than were available in the previously discussed studies. Two studies by Gadnoti et al. (2010) at the ECMWF and Gelaro (2011) at the NOAA/NASA Joint Center for Satellite Data Assimilation (JCSDA) demonstrate the importance of AMDAR data to the global observing system. The ECMWF results from June 2009 in Fig. 3 show that AMDAR data were the fourth most important data set in 24 hours NWP forecasts.

In the ECMWF experiments, the three most important data types were microwave (AMSUA) and hyperspectral infrared (IR) data (notes as IASI and AIRS) from polar orbiting satellite sounders. Unlike AMDAR data (noted as AIREP in this figure), the satellite data sets provide full global data coverage,

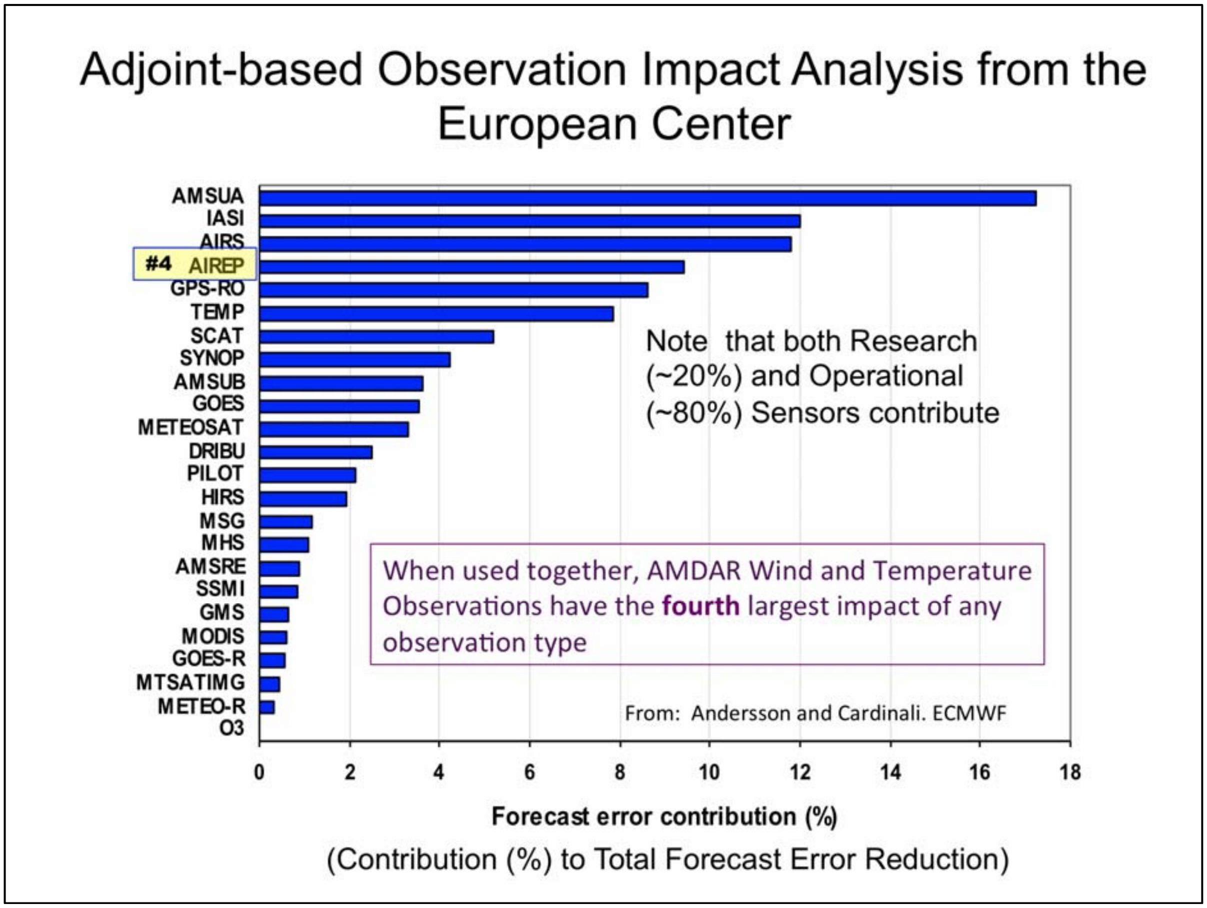

Figure 3: Impact of various different data sets on accuracy of 24-hour ECMWF forecasts (Based on Gadnoti et al, 2010)

although at lower vertical and horizontal resolution than provided by AMDAR data. The AMDAR data were shown to make a nearly 10% improvement to the forecasts for the month, more than either Global Positioning System (GPS) Radio-Occultation (GPS-RO), rawinsonde (TEMP) data or surface synoptic reports.

The results from JSCDA using the Global *Modeling* and Assimilation Office assimilation and forecast system presented in Fig. 4 showed similar findings. In the JCSDA DA system, the AMDAR data (noted here as Aircraft) proved to be the third most important data set, in this case behind AMSUA and the combination of Rawinsondes and Dropwinsondes (noted as RaobDsnd). In these tests, the AMDAR data contributed almost 15% of all data impacts and proved to be more important than hyperspectral IR satellite data. Overall, more than ½ of the AMDAR reports were shown to have positive impact.

The results shown here from the ECMWF and JCSDA were supported by similar results from the US Navy and the UK Met Office, among others. Other studies showed that, although the availability of many different data sets is essential for sustaining improvements in NWP into the future, the AMDAR data were by far the most cost-effective data set currently available. Although several satellite systems and Rawinsonde data showed higher impacts than AMDAR reports, the annualized price of AMDAR data are <10% that of the costs of rawinsondes and <1% of the operational polar satellite systems. It was thought that one reason for the large impact from the AMDAR data related both to the

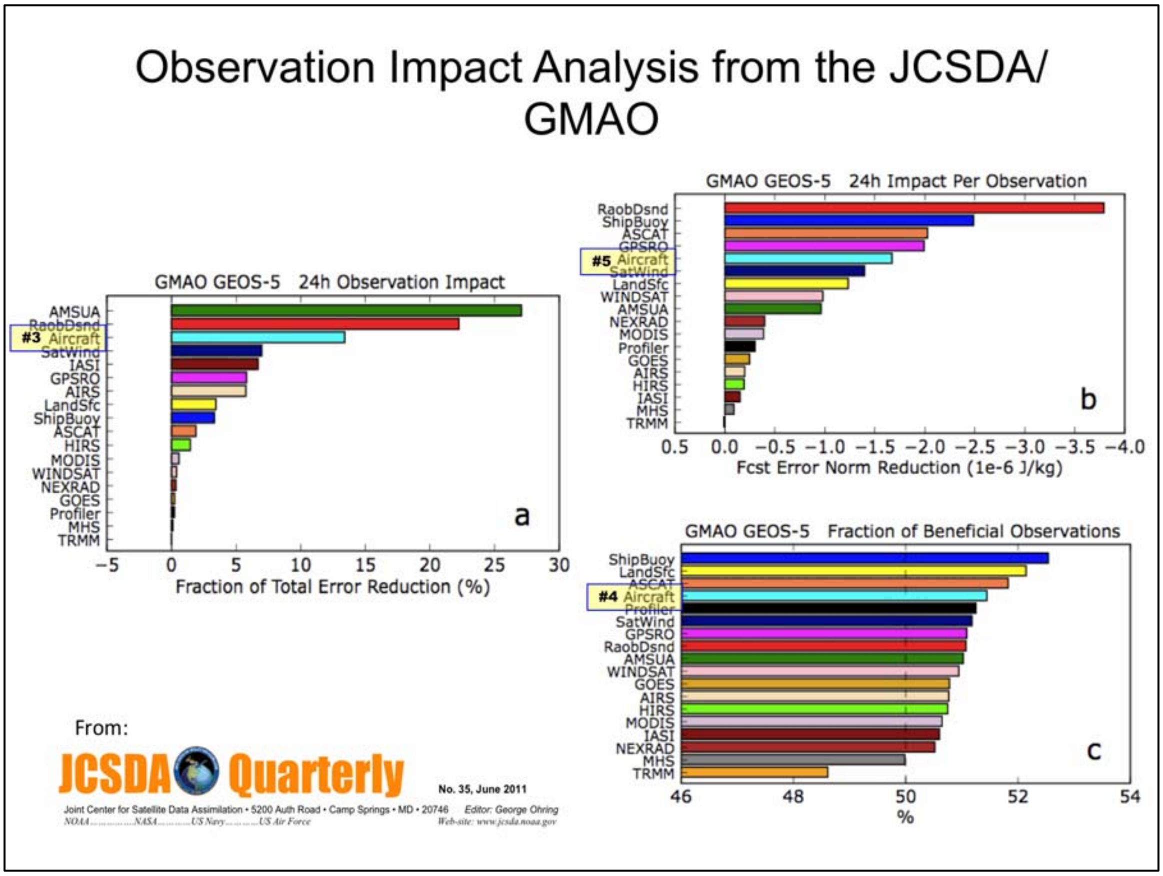

Figure 4: Three measures of the impact of various different data sets on accuracy of 24-hour GMOA forecasts. (From Gelaro, 2011)

fact that the aircraft reports contain simultaneous observations of both wind and temperature and that the data provide the only sources of spatial variations of both of these parameters along the aircraft routes. As such, the data provide not only mass and momentum data but also information about the vorticity near the jet stream. The direct reporting of wind and temperature data also makes the assimilation of these data simpler because no forward data transform models are needed.

<u>Summary:</u> Tests have been conducted by numerous NWP centers over the past decade to assess the impact of various observing systems on the skill of global NWP systems. Results show that most data sets provide important information for improving forecasts, either for individual events or long-term performance. Although satellite microwave observations have the largest influence on 24 hours global forecasts with their global, all-weather coverage, AMDAR observations have become a critical component of operational NWP systems around the world. Although AMDAR data have their greatest influence in the areas and around the levels where they are most abundant, they impact on forecast forecasts extends to 48 hours and beyond. Local impacts can be greater at shorter ranges in areas of higher data density.

<u>References:</u>

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