WORLD METEOROLOGICAL ORGANIZATION

Distr.: RESTRICTED
CBS/OPAG-IOS (ODRRGOS-5)/Doc.5, Add.1)
(21.VI.2002)

COMMISSION FOR BASIC SYSTEMS
OPEN PROGRAMME AREA GROUP
ON INTEGRATED OBSERVING SYSTEMS

ITEM: 4

EXPERT TEAM ON OBSERVATIONAL DATA
REQUIREMENTS
AND REDESIGN OF THE GLOBAL OBSERVING SYSTEM

Original: ENGLISH

REDUCED SESSION

OXFORD, ENGLAND, 1 – 5 JULY 2002

STATUS AND RESULTS OF OSEs

(Submitted by Dr. Horst Böttger, ECMWF)

Summary and purpose of Document

Attached in Annex is an extract from the Draft Final Report of the 12th Session of the COSNA Scientific Evaluation Group which was held at ECMWF, Reading, 21-22 May 2002. Chapter 5 of the report summarises the impact studies carried out by the SEG since the last session.

ACTION PROPOSED:

The Expert Team Members are invited to note and consider the results from the SEG OSEs.

ANNEX: Extracts from the Draft Final Report, Scientific Evaluation Group (SEG), Twelfth Session, ECMWF, Reading, U.K., 21-22 May 2002

ANNEX

5 IMPACT STUDIES

5.1 Review of impact studies

5.1.1 ECMWF(2)

Dr Erik Andersson presented the results from three studies related to observations reported with a high frequency in time:

(i) hourly surface pressure

(ii) hourly vertical wind profiles from European profiler network

(iii) temperature and wind measurements taken during aircraft ascent and descent over North America and Europe.

The impact of hourly surface pressure and also wind observations (SYNOP, SHIP and DRIBU) has been evaluated in the context of ECMWF's operational 4D-Var data assimilation system. The study period was 1-31 May 2001. The globally available observations from the main synoptic hours at 00, 06, 12 and 18 UTC were used in the experiments. Only the data from the intermediate hours were excluded. The hourly surface observations are found to have a positive impact in the short-range forecast in those areas where such data are available (i.e. the North Atlantic and the southern oceans where other data are relatively sparse). The global exchange of all hourly surface observations for use in a 4D-Var system appears to be beneficial for NWP.

The impact of observations from the European profiler network was tested during the period 1-31 May 2001. Only platforms producing consistently high quality data were used in the experiment. Only some marginal impact from the extra data was found. Operational use of the data was implemented at ECMWF in April 2002 but constant monitoring of the quality of the observations is required.

Vertical profile data from aircraft were denied over North America and Europe for the periods 1-31 January 2001 and 1-31 July 2001. All aircraft data (T, U, V) between the ground and 350 hPa were excluded from 25-60N, 120-75W and 35-75N, 12.5W-42.5E. The impact of the wind and temperature profiles from the aircraft observations taken during ascent and descent can be detected in the increment field of geopotential height in the free atmosphere. Forecast errors are reduced over North America, the North Atlantic and Europe. The signal propagates eastward with forecast time and is clearly visible out to Day 5 of the forecast and beyond. The atmospheric profiles from aircraft appear to have a significant impact on the 4D-Var data assimilation resulting in improvements of the short and medium range forecast over North America, the North Atlantic and Europe. The results support the expansion of the coverage of aircraft observations including the observations taken during ascent and descent from other parts of the globe.

Mr Jean-Noel Thepaut reported on the results of satellite-related impact studies Four Observing System Experiments (OSEs) have been performed. The goal was to respectively evaluate the impact of water vapour Clear Sky Radiances (CSR) from Meteosat-7, GOME/SBUV ozone products, Quikscat surface winds and MODIS polar Atmospheric Motion Vectors in the ECMWF assimilation system. The first three OSEs have been motivated by plans for operational implementation, the last one being performed in the context of a collaboration between CIMSS and ECMWF.

The assimilation of Geostationary WV CSR from Met-7 has shown that adjustments of humidity fields were made in areas of model deficiencies. A better fit to other water vapour satellite data was observed (HIRS-12 and AMSU-B) as well as an improved fit to tropical PILOT observations. The impact on scores was neutral to slightly positive.

The assimilation of ozone columns from GOME and ozone profiles from SBUV shows an improvement of the total column ozone field in the ECMWF model. The large

scale structure of stratospheric ozone is also improved. Problems remain with the specification of the ozone background errors used in the assimilation and in particular the vertical distribution of the total column increments in the vertical. The experiments also show a potential of 4D-Var to extract wind information from the ozone tracer.

The pre-operational assimilation experiments of Quikscat surface winds (thinned at 50 km and rainflag quality controlled) has shown several cases of large tropical tracking and surface wind improvement. An improved fit to independent ERS-2 surface winds was also observed. The rain contamination remains an issue since a lot of data cannot be used in crucial areas. Overall the assimilation of Quikscat has a significantly positive impact in the southern hemisphere.

Three weeks of assimilation of experimental MODIS polar atmospheric motion vectors has been performed in the 3D-VAR configuration of the ECMWF system. With a tight quality control on model orography, the assimilation of these data shows a slightly improved fit to the PILOT data in the area, a dramatic improvement of scores over North Pole, which remains substantial over Northern Hemisphere.

5.1.2 Deutscher Wetterdienst

Dr Alexander Cress provided a summary of impact studies carried out by DWD.

The past year was predominated by the migration of our global and local assimilation and forecast system from the old Cray T3E to the new IBM RS/6000SP computer system, including a substantial change in our data base system. With the new computer system we are now able to run a 3-hourly data assimilation cycle with a time window of +/- 1.5 hours. An impact study comparing the 3-hourly cycle to the former 6-hourly cycle has been performed. The new data base system has enabled us to use additional aircraft data (ACARS) in our data assimilation. The impact of the additional ACARS has been studied. In addition, a set of data denial experiments has been performed to study the impact of various components of the surface observation network on the performance of the DWD's global weather prediction system for a time period in summer 2001. Another OSE has been conducted to estimate the impact of PAOB data on the forecast quality of the Southern Hemisphere. The results of all of these studies will be presented.

3-hourly data assimilation cycle on the new IBM system

The DWD, like many other NWV centers, use optimal interpolation schemes to produce global analyses at 00, 06, 12 and 18 UTC, using observations in a window of +/- 3 hours around these analysis times. In cases of fast moving storms, the observation window is too large, leading to strong "smearing out" of information and thus to erroneous forecasts. By reducing the observation window from +/- 3 hours to +/- 1.5 hours the temporal interpolation errors will be reduced, but unfortunately not all available observations will be used at the four analysis times. With the new IBM RS/6000SP computer system the DWD's global data assimilation is able to use a 3-hourly assimilation cycle producing analyses at 00, 03, 06, 09, 12, 15, 18, 21 UTC. The observation window is +/- 1.5 hours around the analysis times. Due to the four additional analyses, all available observations are used. Particularly, more synop-, aircraft-, and satellite data are processed.

An impact experiment covering one month has been performed to investigate the influence of the new 3-h data assimilation cycle on the NWV system's forecast quality. Overall, an increase in forecast quality over all areas can be demonstrated. The benefit is greatest on the Southern Hemisphere and over Europe. It is noteworthy, that the number of extremely erroneous forecasts in the experiment decreases substantially.

Additional aircraft data

Due to a new data base system at the DWD, additional aircraft data (ACARs) can be used within the data assimilation system. The ACARs consists of data from the ascent and

descent phases of the aircraft as well as of flight level data. The amount of usable aircraft data has almost doubled with the inclusion of the additional ACAR data.

An impact study can be used to deduce the positive benefit of the new aircraft data over Europe and the Northern Hemisphere. The benefit is highest over Europe, due to the fact that the new aircraft data are concentrated mainly over the U.S.

Surface observations

In addition to several OSE's for a *winter* period, several impact studies for a *summer* period were conducted, in which the following surface observations were excluded from the routine assimilation and forecast system:

- Ship observations;
- Buoy observations;
- Synop, ship and buoy observations;

All OSE's were run for the period of 10 July to 31 July 2001, using the DWD's 4th generation Global-Modell (GME).

The following results have been obtained:

- Withholding all surface observations (synop, ship, buoys) results in a large deterioration of the forecast quality;
- Benefit is higher in the Southern Hemisphere and Tropics than in the Northern Hemisphere;
- Impact of ships or buoys alone is less but noticeable;
- As opposed to winter cases, benefit of buoys are slightly higher than ships in the Northern Hemisphere;
- Benefit of buoys is slightly greater than that of ships in the Southern Hemisphere;
- Neither ship nor buoy observations had any impact in the Tropics;
- In individual cases, ships or buoys have a significant impact on the forecast quality for Europe and the whole Northern Hemisphere;
- Overall, the impact for the summer period is less than for the winter period.

PAOB observations

The Australian Bureau of Meteorology prepares manual analyses of mean sea level pressure over Southern Hemisphere twice a day, based on satellite imagery, ship and buoy reports and synoptic observations. A set of point estimates of mean sea level pressure, called PAOB's is made from these manual analyses.

An impact experiment has been performed using not only the standard observational data but also the PAOB observations in the Southern Hemisphere, covering the period from 20 March to 10 April 2002. Using PAOB observations results in a substantial increase in forecast quality for the Southern Hemisphere.

5.1.3 UKMO

An overview of impact studies carried out by UKMO was presented by Dr Richard Dumelow.

Improvements in the processing of satellite data

The following three changes in the processing of satellite data were made to operations on 17th October 2001.

Increased use of ATOVS over sea ice

The emissivity of sea ice was previously set at a constant 0.92 where the fraction of a grid box containing sea ice (the sea ice fraction) was greater that 20%. The emissivity from sea ice is now variable and depends upon the sea ice fraction, taken from the NCEP sea ice analysis, and the sea ice type. The sea ice type is defined as 'new' or 'multi-year'. Recently formed or 'new' sea ice has different emission properties to older or 'multi-year' ice which tends to be covered in snow. This operational change resulted in an improved fit to radiances at T+6 over the ocean near sea ice and over sea ice. The impact on RMS scores was neutral in the Northern Hemisphere, but slightly positive in the Southern Hemisphere where RMS height errors fell by 1-2% at and below 500 hPa at all forecast ranges up to 6-days.

Increased use of ATOVS data in cloudy conditions

There are good reasons to observe cloudy regions of the atmosphere. It has been found that model background errors are systematically higher in cloudy areas, and also these regions are most likely to be more 'sensitive' to synoptic development. Thus the ATOVS thinning algorithm was modified so that observations taken in cloudy conditions were preferentially selected if possible. The observations are selected in regions where the microwave sounder detected no cloud, but the infra-red sounder did. Such regions tend to contain cloud with ice or small water droplets, but not large water droplets or precipitation. This modification resulted in a much-improved fit to radiances at T+6, and a reduction in RMS height errors of 2-3 % at T+24 and T+48 in the Southern Hemisphere, and a 1-2 % reduction in the Northern Hemisphere.

Doubling of observation errors for AMV data

A doubling of the observation errors for AMV reports brings the observation errors used by the Met Office in line with those used by other Centres.

Impact of observations on mesoscale model forecasts of precipitation

A case selection technique has been used to pick out cases where observations assimilated over a 6-hour period produced significant improvements in the skill of short-range forecasts of precipitation produced by the mesoscale model. Cases were chosen from periods April 2000 to October 2000 and July 2001 to January 2002. It was found that the analysis from the Moisture Observation Processing System (MOPS) produced noticeable impact on the largest number of occasions. Surface, aircraft and radiosonde observations provided benefit on approximately an equal number of occasions.

The Impact of Data from E-ASAP on NWP

The E-ASAP field experiment took place in September and October 2001 as part of the EUCOS Studies Program. During the experiment, extra ASAP reports were taken over the North Atlantic and the Azores radiosonde reported four times a day. On average, about 6 extra observations were made over the North Atlantic at any particular time. An Observing System Experiment was run using the Met Office global model to assess the impact of the data. The overall impact of the extra data on the mean scores was neutral, although two cases were found where the RMS scores of the T+96 forecast versus European sondes were noticeably improved. The small impact is probably due to the low number of reports being available at a time when prevalent synoptic conditions over the North Atlantic were anti-cyclonic.

Global data denial experiments

Global data denial experiments have been performed to assess the overall performance of the Met Office data assimilation scheme. Using July 2001 data, runs have been performed in which the following data types were denied: radiosonde, aircraft, surface, satellite radiances, atmospheric motion vectors, and all satellite data. Additional runs denying the surface observation types SYNOP, buoys, ships and all marine (buoys plus ships) were also run. Initial analysis of the results suggests:

- Satellite data are the most important source for forecasting gepotential height in the Northern Hemisphere, Tropics and Southern Hemisphere.
- Sonde data provide the most important source of information for forecasting wind in the Northern Hemisphere, but satellite data are the most important source in the Tropics and Southern Hemisphere.
- Aircraft data are as important as sonde data for geopotential height forecasts in the Northern Hemisphere at T+144.
- In the Southern Hemisphere, AMV data have most impact when satellite radiance data are not available.
- Surface pressure observations are essential for MSLP forecasts, but there may be significant redundancy in the network, particularly in the Northern Hemisphere.

5.1.4 HIRLAM

Dr Xiang-Yu Huang presented a summary of impact studies carried out by HIRLAM.

ATOVS AMSU-A

The HIRLAM 3D-Var system is currently set up for assimilation of AMSU-A channels over ocean only, after a bias correction, a deep cloud check and a thinning to a minimum distance of 150 km. Different approaches have been tried for selecting the observation error covariance matrix R, both diagonal or non-diagonal.

There have been a number of intensive impact studies. An overview is given in Table 1.

Table 1: Overview of impact studies.

Period	Model	Data Source	Analysis window	Other Information
Dec 1999	SMHI 44 km	ECMWF global archive BUFR data	3h	Diagonal R (Cloud mask bug)
1-6 May 2000	SMHI 22 km BALTEX	ECMWF global archive BUFR data	3h	(Cloud mask bug)
Feb 2000	DNMI 50 km	DNMI Oslo antenna, NOAA-15 only	6h	Non-diagonal R
21 May-7 June 2001	DNMI 50 km	DNMI Oslo antenna, NOAA-15 only	6h	Non-diagonal R
Dec 2001	DMI-G 0.45	DMI Denmark and Greenland antennae	3h	Non-diagonal R
Jan 2002	DMI-G 0.45	DMI Denmark and Greenland antennae	3h	Revised non-diagonal R
Feb, Mar, Apr 2002	DMI-G 0.45	DMI Denmark and Greenland antennae	3h	Revised diagonal R

Some of the impact studies are done with an operational environment using ECMWF forecast boundaries, using ATOVS data down-linked from the satellite at local antennae and processed with AAPP in near-real-time. The coverage of these data is limited by the view of the local antennae. Other studies are done offline and use archived ATOVS BUFR data from the ECMWF MARS archive and ECMWF analyses as lateral boundaries. The coverage of these data is not limited by the view of the local antennae, and by the timeliness constraints in an online run, and thus have a better data coverage.

The December 1999 run covered a period when several strong storms hit Europe. The average statistics shows a slight positive impact of using AMSU-A data for this period. Closer examination of the time series of the scores, revealed that most of the

impact seen came from one single event, which was on the 27th when the storm hit France.

The May 2000 run gave a neutral impact of the AMSU data, which may be due to the bugs in the assimilation code that was used.

The February 2000 and May 2001 experiments showed a positive impact from AMSU-A data. For the February experiment most of the impact was found over the North-Atlantic ocean. Only a slight impact was seen when validating against the whole EWGLAM radiosonde dataset (which is biased towards continental Europe), but when validating against three ocean radiosonde stations in the North Atlantic, the impact was much more significant. This was not seen in the May 2001 experiment, but here the impact using the whole EWGLAM dataset was bigger.

The December 2001 run gave a neutral impact of the AMSU-A data. The run seemed to be influenced by a non-optimal choice of observation error covariance matrix. A non-diagonal R was used, and later an adjustment was made where correlations between some of the channels were set to zero. A revised setup with this adjusted R was run for January 2002, and this resulted in a positive impact from AMSU-A data.

The most recent DMI experiments were performed with a modified diagonal R. There were clear positive impact of ATOVS AMSU-A data in March and April.

Ongoing work with ATOVS data in HIRLAM includes taking HIRS moisture channels into use and the use of observations over sea ice. There are also plans on developing use of AMSU-B moisture data.

GPS-ZTD

The basic quantity measured by the ground-based GPS system is the slantwise delay of the GPS radio-signal between the GPS satellites and GPS ground stations. A number (5-10) of such slantwise delay measurements are mapped into a Zenith Total Delay (ZTD). Provided independent measurements of surface pressure are available at the GPS ground station, a further pre-processing into the Zenith Wet Delay by subtraction of the Zenith Hydrostatic Delay can be carried out. The wet delay can be further pre-processed to Integrated Water Vapour (IWV). We have chosen to assimilate the Zenith Total Delay (ZTD). Other optional variables also exist in the HIRLAM 3DVAR. Observational errors for ZTD are estimated and tuned. A bias reduction is applied before 3DVAR.

Both at SMHI and at DMI, impact studies have been performed using the 3DVAR system for a two-week period, 9-23 June 2000.

The DMI observation verification indicated a neutral impact over the period. However, for the case of 9-11 June 2000, it is clear that forecasts based on analyses including GPS-ZTD data have a higher skill in predicting significant precipitation, using the high resolution rainguage data over France.

The SMHI results indicate significant precipitation forecast differences, but it was not possible to judge from the available radar verification data whether one forecast was better than the other.

Future work include developments of improved bias reduction schemes, developments of models for the horizontal and temporal correlation of the observation errors, possible utilisation of slant atmospheric delays, data impact studies over longer time periods and using a 4DVAR setup.

SSM/I

A series of experiments was done at DMI for the period from the 25th of November to the 4th of December 1999 with 3 hour assimilation cycles. ECMWF analyses (from 00 and 12 UTC) and 6 hour forecasts (valid at 06 and 18 UTC) were used

as boundaries with a boundary update period of 6 hours. The SSM/I data encoded in BUFR are received from NOAA/NESDIS by ftp. The data are typically available with a delay of three hours. Three experiments were made: a control run with conventional observations, a run with IWV observations from the SSM/I 1D-VAR output and a run with wind squared observations from the SSM/I 1D-VAR output.

The analyses and forecasts were verified against observations. The overall verification scores do not change very much when including the SSM/I data.

The main priorities are to develop a screening procedure for the 1D-VAR output and to recalculate brightness temperature biases and observation errors. We are in the process of making new set-up based on data from January 2002. The fact that the data is received with a delay of three hours needs to be addressed. Various options for running re-assimilation will be investigated.

SeaWinds scatterometer data

The SeaWinds scatterometer instrument is currently flown on the QuikScat polar orbit (100 minutes/orbit) satellite. The data coverage is over ocean only, and the HIRLAM area of interest passes through the orbit plane at approx. 0600 and 1800 hrs (Z). The highest resolution is 25 km, and the data delay is 3 hours (by ftp from NOAA/NESDIS). The observation parameter is the 10 m wind vector. Unfortunately, since each QuikScat wind observation consists of up to 4 possible wind solutions, it becomes necessary to use model wind to choose the correct wind solution. The observations are also sensitive to precipitation. Recently, parallel runs were performed at DMI showing minor positive impact from the data.

The plan is to have HIRLAM 3D-VAR capable of assimilating QuikScat by June 2002. The first test version featured: NOAA/NESDIS QuikScat BUFR read directly, QuikScat data stored in FORTRAN modules, KNMI rain flag algorithm used, 25 km QuikScat analyzed using DAR method (using either: 1) Wind speed and direction, 2) wind speed only or ignoring the observation.), FGAT and VarQC (not tested), simplified calculation of 10 m model wind ("forward model").

Doppler radar wind

Doppler radar data impact has been investigated and reported. The data were collected from the Swedish radar network and used in the form of VAD and radial wind super observations. A 10-day period, 1-10 Dec 1999, was selected. This period is characterized by the "Danish Strom".

The observation fit statistics reveals a high quality of the radar data and reasonably tuned error statistics. The observation verification scores indicate improved forecasts of winds and temperature in the low and middle troposphere. The improvements are similar when using radar data as VAD wind profiles or as radial wind super observations.

Future work include more extensive parallel data assimilation experiments, further tuning of error statistics and quality control, and preparation for handling velocity ambiguities.

SYNOP cloud and precipitation

A nudging scheme has been developed for assimilating cloud- and precipitation data into HIRLAM. The information appears to be of great value since the focus of short range forecast is on predicting local weather parameters, *e.g.,* precipitation, cloud cover and temperature. The assimilation acts on top of an already existing analysis for other parameters based on HIRLAM 3DVAR. The first tests on 3-D forecast cases indicate a good skill of the assimilation method. The mean absolute error and bias in cloud forecasts are reduced due to the nudging.

Continuous 3-D tests including objective verification will be carried out at DMI in the future to further diagnose benefits and problems associated with the **nudging scheme**.

5.1.5 METEO-FRANCE

Dr Jean Pailleux presented a summary of impact studies carried out by Météo-France.

When preparing the operational use of some data sets, two observing system experiments have been carried out, one on the profiler data (both US and Europe), and one on the raw ATOVS radiances. Several experiments have been performed, generally on recent periods which are 2 to 3 week long. They have been run with the operational assimilation and forecasting systems (4D-VAR). A significant impact of profilers is found over Europe and North America. The use of raw radiances has also a positive impact with respect to the use of processed radiances (which are currently in operations), except over Europe, and mainly in the Southern Hemisphere.

In order to evaluate the impact of tropical radiosondes, an impact study has been carried out on a 3-week period of June 2000, in which all the TEMP and PILOT messages have been removed in the tropical belt (20N-20S). This is one of the basic OSEs recommended by WMO. The study has been done with a uniform T199/31L version of the global model ARPEGE. A 6h-cycling 3D-VAR has been used for the assimilation, where the analysis increments are computed at T127. Analysis differences are generally small, except in the Australia – Indonesia area where they are bigger all the time (half of the removed radiosondes are in this area). 96h ARPEGE forecasts have been run every day from 00UTC and intercompared. On one or two occasions, initial differences are growing and propagating up to 50 or 60 degrees of latitude, at 72 or 96h range.

5.1.6 NCEP (including reports on NAOS and THORPEX)

Dr Stephen Lord informed the meeting on the results of impact studies carried out at NCEP regarding contributions of wind profiler and MDCRS (aircraft) ascent and descent profiles to the accuracy of 0-12 hour forecasts. A short test over three weeks in May 2002 was carried out with the Rapid Update Cycle (RUC-20) denying the wind profiler data. Preliminary results show that the loss of profiler data give a worse fit of the analysis to radiosonde data which carries through into the 12 hour forecast. The tests with the denial of the aircraft ascent and descent data were underway.

NAOS and THORPEX updates

The NAOS activities in the US are now focussing on the development and testing of meso-scale observing systems for supporting high impact weather event prediction. The Science and Technology Planning includes studies of the observing system requirements and the utilisation of new platforms and technologies such as dual polarization or phased array radar, the NPOESS system, GOES-R and unmanned aerial vehicles (aerosondes).

THORPEX is a 5-10 year research programme with a goal of improving NWP weather forecast for the 0-14 day lead time. A detailed research plan is being drafted for presentations to WWRP and WGNE in November 2002.

5.2 Review of impact studies initiated by the ET on ODRRGOS

Dr Paul Menzel, Chairman of the CBS/OPAG/IOS ET on ODRRGOS informed the meeting on the status of impact studies, initiated by the ET. The SEG recalled that the ET-ODRRGOS suggested seven OSEs for consideration by NWP centres and asked the OSE/OSSE rapporteurs to engage as many as possible in this work. They include studying the :

- Impact of hourly SYNOPs ;
- Impact of denial of radiosonde data globally above the tropopause ;
- Information content of the Siberian radiosonde network and its changes during last decades;
- Impact of AMDAR data over Africa through data denial in a 4D-Var analysis and forecasting system;
- Impact of tropical radiosonde data ;
- Impact of three LEO AMSU-like sounders, and
- Impact of AIRS data.

The upcoming ET-ODRRGOS meeting (Oxford, UK, 1-5 July 2002) will specifically address the results of the above studies.