BMRC Data Assimilation Progress Report

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Development and Implementation of BMRC 3D-VAR Assimilation System

A new three dimensional variational (3D-VAR) analysis scheme using an observation space formulation is currently being experimentally evaluated in BMRC. This system can use either standard functional representations of background error correlations (as were commonly used within OI schemes) or empirical correlations as obtained from ensembles of analysis-forecast cycles (as implemented by Fisher and Buizza), or statistics of scaled differences between 48 hour and 24 hour forecasts (the so-called NMC method). This 3D-VAR scheme can be used for both global and regional systems. The analysis procedure is based on a series of local sub-volume analyses, with data selection extending significantly beyond the individual analysis volumes. Scattering from observation analysis increments back to the analysis grid-points is performed once all sub-volumes of the required domain have been analysed; this is an important part of ensuring that the analysis is independent of the geometry of the localized solution domains. The inclusion of the direct (3D) assimilation of radiances and the use of alternative coordinates for specifying background error correlations is in progress.

The currently used statistics based on the NMC method of scaled differences are being compared to the statistics based upon ensembles of differences between 6-hour forecast background fields, generated by parallel analysis-forecast cycles with perturbed observations following Fisher and Buizza (ECMWF). The main differences between the statistics generated by the two approaches appear to be (i) the ensemble approach implies shorter length scales, and (ii) the ensemble approach implies more variance in the divergent component of the wind, especially outside the tropics. Parallel assimilation and forecast trials utilising the two alternative structures are in progress.

Global 1D -VAR Assimilation of ATOVS.

The present operational global assimilation system utilises a 1D-VAR retrieval of both NOAA15 and NOAA16 AMSU-A and HIRS radiances, utilising 1D radiances as available from NESDIS. An extended version of this global system has been experimentally implemented and tested with 50 vertical levels (with the top level at 0.1 hPa). This version of the system allows the full forward calculation of ATOVS radiance first guess values in the 1D-VAR retrieval scheme still using level 1D ATOVS radiances. This obviates the need to interpolate NESDIS temperature retrievals above this level, as is the case in the current 29 level operational system, which has a top level of 10 hPa. Extensive global assimilation experiments have been conducted during year 2000 (both T79/L50 and TL239/L50) and medium-range prediction performance in the stratosphere has been substantially improved .

In the immediate future 1C radiances, will be utilised and each instrument (HIRS or AMSU-A or B) in the ATOVS instrument package will be treated as a separate observation. Additionally direct readout/processing of radiances at BoM ground-stations delivers 1C radiances which are desirable in support of early cut-off regional assimilation. Initial experiments with the use of 1C AMSU-A radiances alone have indicated a deficiency arising from the absence of the infra-red HIRS; incorporating these HIRS radiances and and appropraite cloud clearing strategy is the focus of present work.

Regional 1D -VAR Assimilation of ATOVS

The online 1D-VAR ATOVS radiance retrieval scheme, implemented operationally within the global system (GASP), has also been integrated with the Bureau's Limited area Assimilation and Prediction System (LAPS), as part of the effort to unify the data assimilation component of the local and global forecasting systems. The current operational version of LAPS has 29 vertical levels up to 50 hPa and NESDIS retrievals are used to extend the first guess profiles above this. The 1D-VAR retrievals are used over the sea and below 100 hPa.

Extensive near real-time assimilation and forecasting experiments have been conducted to test the performance of the LAPS 1D-VAR system. Data assimilation was performed by means of the cold-start strategy employed in the Bureau's operational LAPS system in which three six-hourly assimilation cycles leading to the base-time of the forecast are built on a GASP first-guess, with lateral boundary conditions also provided by the GASP system. For the second and third cycles, in which LAPS forecasts provide the first guess, radiance bias corrections calculated and updated continuously by the LAPS 1D-VAR system were used. Only the same observational data as available to the operational LAPS system, which employs a two hour cut-off at the forecast base-time, were presented to the experimental 1D-VAR analysis system; these included NESDIS 1D ATOVS radiance data.. (NESDIS temperature and moisture retrievals only are available to the operational system). S1 skill scores calculated from the 1D-VAR forecasts and averaged over a four month period show a significant improvement over those obtained from the operational system: the MSLP forecasts are improved by 1.1 S1 points at +24 hours and 0.8 S1 points at +48 hours. Forecasts of 850 hPa geopotential height show the most marked gains, with an improvement of 1.9 points at +24 hours. The LAPS 1D-VAR system is to be implemented operationally in March 2002.

Work is underway to test the 1D-VAR system in an extended version of LAPS with an increased number of vertical levels and the model top raised to 0.1 hPa, following similar extensions to GASP. This eliminates the need for NESDIS retrievals and will facilitate the use of locally received and processed ATOVS radiances whose timeliness will improve the amount of data available to the operational LAPS system. Early results indicate similar performance to the 29 level system at the surface and further gains to forecast skill above 500 hPa.

Global Assimilation of Scatterometer Data

Scatterometer data (Quickscat) is now being assimilated on an experimental basis within the global GASP system, with modest positive impact on medium range prediction , chiefly in the Southern Hemisphere. Quality control procedures have been supplemented with background checks of wind direction, to remove incorrectly dealiased data.. It is planned to experiment with a more physically based quality control system. There is some evidence of contention with other observation types, chiefly cloud drift winds, which seems to be due to a lack of boundary layer structure in the background covariance. The scatterometer data is expected to be included into the operational global system as part of the next major upgrade.

Additionally intercomparisons (several months) of Quickscat wind vectors with the current operational GASP and LAPS assimilation and prediction (where the Quickscat data has not been assimilated), have shown that the model analyses and short term predictions (18 and 24 hr) have no marked systematic biases relative to the scatterometer . This has been conducted in the context of clarifying/verifying the behaviour of the marine boundary layer in the models..

Generation and Quality Control of GMS-5 Atmospheric Motion Vectors

High spatial and temporal resolution atmospheric motion vectors from GMS-5 are generated routinely at the Bureau of Meteorology (BoM) for operational and research applications. Motion vectors are determined by tracking features in infrared, water vapour and high resolution visible imagery using all available Stretched VISSR images arriving at the BoM. This currently results in wind vectors being generated four times per day over the full disc from images separated by half an hour and every hour where imagery is available hourly. Recently, hourly winds have only been available over the Northern Hemisphere because of the restricted observation cycle of GMS-5.

The benefit of these high resolution winds, generated from both images separated by half an hour and one hour in assimilation in the LAPS NWP system for the Australian Region has recently been quantified in a regional impact study. A key element in utilising the winds has been quality control of the vectors both in the Northern and Southern Hemispheres. Initially, a locally developed methodology to estimate expected errors was based on image correlations, internal consistency of the vectors and differences from the model first guess. Currently, use of the QI approach, developed at EUMETSAT, is being tested to optimise the selection and use of vectors for analysis.

Validation of GPS based Total Precipitable Water estimates

Following activities at other major meteorological centres, a study of GPS based retrievals has been undertaken by Curtin University (Dr. N. Penna) and the Bureau of Meteorology Research Centre (BoM). It aims to investigate potential improvement to meteorological prediction by assimilating GPS estimated Total Precipitable Water (TPW). Derivation of realistic quality indicators for GPS estimated atmospheric water vapour is the first step in this direction. Seventeen GPS stations are included in the study, stretching from Cocos Island in the tropics, through the Australian Continent to Macquarie Island and Antarctica (3 stations). Using pressure and temperature estimates from collocated or nearby surface stations, and GPS data, TPW estimates were computed over the year 2000 for all these stations. For validation purposes, these were subsequently compared with Integrated Precipitable Water (TPW) computed from radiosonde reports, co-located or close to GPS locations. The comparison with 14 available radiosondes is for the period Jannuary - December 2000. The comparison statistics indicate the largest biases for Antarctica. The standard deviations of (GPS - radiosonde TPW) were largest for the sites with highest atmospheric moisture content or where the distance between the GPS station and the radiosonde / surface station is high. Comparison of GPS TPW with estimates from operational analyses (BoM and ECMWF) for the year 2000 is now being undertaken.

Data Management Developments

The Meteorological Archival and Retrieval System (MARS) is a software package developed at the European Centre for Medium Range Weather Forecast (ECMWF). This software has been made available to the Bureau of Meteorology.

BMRC examined and implemented a MARS prototype system in late 1998 to address a number of data management issues at BoM, where the current operational implementation data archive based on Neons/ORACLE database is considered inadequate to support research and climate activities. In late 2001, following successful prototyping of this system, MARS has now been implemented at BoM, on a 4-node 12-processor IBM SP2 system that couples directly to the Bureau's 8-drive StorageTek SILO tape system and SAN disk storage farm. High-speed HIPPI links connect the SP2 to the Bureau's NEC SX5 supercomputers as well as a number of key research and operational platforms.

MARS is currently used to archive selected global model and global ensemble system output, in addition to research experimental data.. It is expected that MARS will gradually replace the Bureau operational real time Neons/ORACLE database as the repository of all archived NWP model and observational data.