Global Impact Studies at the German Weather Service (DWD)

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Abstract

This presentation will give a summary of recent progress in assimilation of satellite sounding data, satellite winds and other satellite and in-situ data at DWD, along with an outlook of future developments. In all cases, the quality and usage of new observations were tested by observation system experiments (OSE) and led to a better understanding of the role of the data within the global observation system and a deeper insight into the used assimilation scheme.

Major key activities of the last years were the assimilation of bending angles from GPS radio occultations and the estimation of quality and possible use of the IASI instrument onboard of Metop A. Some results will be presented. Recent work on the use of AMV wind data has been focussed on replacing GOES 12/13 and MTSAT-1R with MTSAT-2R. Additionally, new polar wind products (AVHRR winds, direct broadcasting winds) became available. Further tests are being carried out using AMV wind information over land. The quality and usage of scatterometer wind data (QuikScat, ASCAT, OSCAT) in our data assimilation system is a further topic which will be addressed. Furthermore, the impact of aircraft humidity data over the US will be presented along with results of an aircraft temperature bias correction scheme. Additionally, an outlook of future activities, such as the development of a hybrid ENKF-3DVAR system, the use of radiances over land and in cloudy conditions and the preparation for upcoming satellites and instruments (NPP, ADM-Aeolus, SMOS, etc.) will be given.

Observing System Experiments using the NCEP Global Data Assimilation System

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Observing system experiments (OSEs), during two seasons are used to quantify the contributions made to the forecast quality by conventional rawinsonde data and remotely sensed satellite data. The impact is measured by comparing the analysis and the forecast results from an assimilation-forecast system using all data types with those excluding a particular observing system. For these observing system experiments, forecast results are compared through 168 h for periods covering more than a month during both the summer and winter seasons of each hemisphere. The assimilation –forecast system used for these experiments is the National Centers for Environmental Prediction (NCEP) Global Data Assimilation System (GDAS) and the Global Forecast System (GFS). The May 2011 version of the GDAS/GFS, at a resolution of T574L64 will be used. The case studies chosen consist of 67 days beginning 1 December 2010 and 1 August 2011. The first 15 days are ignored to allow the GDAS/GFS to adjust to the missing data. Impact statistics are derived from the 45 days following the adjustment period. Anomaly correlations (ACs) of extratropical geopotential heights by hemisphere, root-mean-square (RMS) errors of winds in the tropics, forecast impacts (FIs), and hurricane track forecasts are evaluated for experiments run during both seasons.

Uncertainty in Operational Atmospheric Analyses and Re-Analyses

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This talk will describe uncertainty in atmospheric analyses of wind and temperature produced by operational forecast models and in re-analysis products. Because the “true” atmospheric state cannot be precisely quantified, there is necessarily error in every atmospheric analysis, and this error can be estimated by computing differences (variance and bias) between analysis products produced at various centers (e.g., ECMWF, NCEP, U.S Navy, etc.) that use independent data assimilation procedures, somewhat different sets of atmospheric observations and forecast models with different resolutions, dynamical equations, and physical parameterizations. These estimates of analysis uncertainty provide a useful proxy to actual analysis error. For this study, we us a unique multi-year and multi-model data archive developed at NRL-Monterey.

It will be shown that current uncertainty in atmospheric analyses is closely correlated with the geographic distribution of assimilated in-situ atmospheric observations, especially those provided by high-accuracy radiosonde and commercial aircraft observations. The lowest atmospheric analysis uncertainty is found over North America, Europe and Eastern Asia, which have the largest numbers of radiosonde and commercial aircraft observations. Analysis uncertainty is substantially larger (by factors of two to three times) in most of the Southern hemisphere, the North Pacific ocean, and under-developed nations of Africa and South America where there are few radiosonde or commercial aircraft data. It appears that in regions where atmospheric analyses depend primarily on satellite radiance observations, analysis uncertainty of both temperature and wind remains relatively high compared to values found over North America and Europe.

The distribution and magnitude of uncertainty in wind and temperature analyses have implications for numerical weather prediction and climate monitoring. The future global observing network may be improved by including a greater diversity of observation types, compared to the current system which is heavily dominated by satellite radiance data. In particular, the addition of high-quality tropospheric wind observations, such as might be provided by space-based lidar, may be a useful supplement to radiance data, particularly if new observations are effectively targeted to regions which currently have large analysis uncertainty.

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Use and Impact of GPS Radio Occultation Data in GRAPES

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Abstract

The radio occultation(RO) sounding technique that uses signal transmitted by Global Positioning System(GPS) has evolved as an important global observing technology. The assimilation of GPSRO refractivity has been implemented in GRAPES (Global and Regional Assimilation Prediction System), new generation numerical model system in China, and its impact will be assessed in this paper. After a brief introduction to the global GRAPES-3DVar, results of a series of experiments with and without GPSRO data from COSMIC and GRAS mission are showed. The results of the assimilation experiments show that the GPSRO measurements provide good temperature information not only in the upper troposphere and lower stratosphere but also in the lower troposphere, particularly in the southern hemisphere, which produce a clear improvement in the RMS and Bias fit to NECP analysis. The accuracy of analyzed water vapor is also improved, as verified against independent radiosonding and dropsonde observations that had not been used in these experiments. The wet bias of the assimilation system in the tropical ocean is reduced after assimilating more GPSRO observations below 4Km altitudes. The forecast impact experiments are also shown to have a positive impact on short- and medium-range forecast after assimilation GPSRO data, which is a beneficial, persisting and cumulative effect.

Patrick Moll, Meteo-France

Data impact studies in the global NWP model at Meteo-France

In recent years, several experiments on the impact of observations have been conducted at Meteo-France. Most of them are related to satellite data. Thus, we increased the number of IASI channels, including humidity channels, and introduced cloudy IASI and AIRS data. We also added AMSU A and B over land and see-ice surfaces, while SSM/I-S data from three satellites are currently assimilated. One of the most interesting impacts came from GPS radio occultation and scatterometer winds data.

Some improvements in the use of conventional observations have also been done: introduction of ground-based GNSS data over Europe, correction of the radiosondes biases and fine-tuning of the observation standard deviation errors.

Finally, in order to diagnose the sensitivity of the forecast to the observations, we used a linear estimation of the impact of observations based on the calculation of the total energy of forecast error. Thus, we studied the behaviour of some subsets of observation: by type, observed parameter, atmospheric layer or geographic area.

Observation impact estimates using the NCEP GFS/EnKF

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Forecast sensitivity to observations estimated within the ensemble Kalman filter (EnKF) has been investigated. The improved formulation of the method of Liu and Kalnay (2008) was applied to the NCEP Global Forecast System EnKF (GFS/EnKF) with the observations assimilated in the operational global data assimilation system. Some examples of the observation impact estimates will be shown and compared with the adjoint-based estimations. As the most of the state-of-the-art operational data assimilation systems are transitioning to the hybrid variational and ensemble-based system, observation impact estimations within the framework of the hybrid system will be also addressed.

Reference

Liu J., and E. Kalnay, 2008: Estimating observation impact without adjoint model in an ensemble Kalman filter. *Quart. J. Roy. Meteor. Soc.,* **134**, 1327-1335.

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Impact studies with satellite observations at the Met Office

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ABSTRACT

In the last 4 years, the Met Office has conducted many impact studies using satellite observations, as part of the process of improving the use of satellite data in operational NWP and of bringing newly available observations into operational use. In this talk, the most significant results obtained during this period will be summarised, and particularly those with implications for the decisions on the evolution of future observing systems. This includes the impact of: cloud-affected infra-red radiances (AIRS and IASI); infra-red radiance data (IASI) over land; more extensive use of radio occultation and SSMIS data to address assimilation problems in the upper stratosphere and mesosphere; GPS total zenith delay observations; and ASCAT and Windsat surface wind information when Quikscat failed. Most results have been obtained using the Met Office global NWP systems. Also, most are from data-denial experiments, although the impact of satellite data assessed using an adjoint-based sensitivity method will also be shown.

Assessing the benefits of assimilating GPS RO profiles into Global Numerical Weather Prediction Models

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With the launch of COSMIC satellites in April 2006 the availability of GPS Radio Occultation (RO) observations for operational NWP applications began. GPS RO profiles started being assimilated operationally worldwide soon after. The incorporation of COSMIC into the operational assimilation systems was shown to produce a significant improvement in global model skill. For example, experiments at NCEP showed that COSMIC produced ~ 8 h of gain in forecast sill in the Southern Hemisphere extra-tropics starting at day and this gain extended to ~15 h at day 7. After COSMIC, other missions carrying GPS RO receivers became available for operational uses: GRACE-A, MetOp-A, SAC-C, C/NOFS, and TerraSAR-X.

Over the last few years, GPS RO has been proven to be a key component of the global observing system, providing information on the state of the atmosphere that is not contained in other satellite observations. The fact that GPS RO is minimally affected by clouds and precipitation, and provides equal accuracy over land as well as over oceans, are a few of the main reasons for the high value of the GPS RO data. In addition, because GPS RO provides limb-type soundings, profiles are provided at a much higher resolution than those of many other satellite data sources and, thus, are capable of resolving smaller structures. Furthermore, as a result of the unbiased nature of the GPS RO measurements, the assimilation of these data acts as an ‘anchor’ to the model, preventing it from drifting towards its climatology and thus enhancing the assimilation of radiance data.

During the talk, the benefits of adding GPS RO observations into the Global Observing System in terms of global model forecast skill will be presented.

The new NWP system at KMA and some preliminary results of sensitivity test to observational data

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In the middle of 2010, Korea Meteorological Administration (KMA) entirely replaced all of the operational NWP system with the new one based on the UK Met Office UM/VAR (Unified Model/ Variational Assimilation System). The new NWP system has been imported and tested in KMA since 2008 and is currently in operation. As compared with 3DVAR system in old system, 4DVAR data assimilation system is incorporated with the numerical model in the new system. Since we used 4DVAR, the amount of usage for observational data has overwhelmingly increased, especially satellite data such as radiance from NOAA series satellite (ATOVS), MetOp-2 (ATOVS, IASI), Aqua (AIRS), DMSP-16 (SSMIS); Atmospheric Motion Vector (COMS, MTSAT, GOES, METEOSAT7, MSG, MODIS, AVHRR); scatterometer sea surface wind (ASCAT, WINDSAT) and GPSRO (COSMIC, MetOp GRAS). Clearly, we are using conventional data such as Surface (SYNOP, SHIP, BUOY, BOGUS), Sonde (TEMP, PILOT, WindProfiler) and Aircraft (AMDAR, AIREP). We have tried only to use more observation data, however will focus on the study to make better use of observation data through the adjoint sensitivity study to observation data. In this representation, KMA NWP system and used observation data will be addressed, and the result of sensitivity study to some kind of observation data will be presented.

Impact of observations in the Southern Polar area during the Concordiasi field experiment

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The Concordiasi field experiment took place in the autumn 2010. It deployed 640 dropsondes from 13 super-pressure balloons over the Antarctic continent and surrounding seas. This provided an unique opportunity to document the impact of observations in the Southern Polar area. The performance of Numerical Weather Prediction (NWP) models is discussed with respect to the Southern polar area. It is shown that the performance of NWP analyses and forecasts has dramatically improved over the last decade. However large systematic differences remain in analyses from various models for temperature over Antarctica, and for winds on the surrounding oceans. Concordiasi meteorological observations, both at the gondola level and from the dropsondes were used in real-time at Numerical Weather Prediction Centres in the Austral spring 2010. The comparison between short-range forecasts and the data from the field campaign was investigated for several centres in the US, France, Canada, ECMWF, Japan, Germany and the United-Kingdom. Results show that models suffer from deficiencies in representing near-surface temperature over the Antarctic high terrain. The very strong thermal inversion observed in the data is a challenge in numerical modelling, because models need both a very good representation of turbulent exchanges in the atmosphere and of snow processes to be able to simulate this extreme atmospheric behaviour. Dropsondes were shown to have a positive impact on the forecast performance in four different models, with an impact of the same order of magnitude as the one brought by radiosondes. The total short-range forecast error reduction produced by assimilation of dropsonde observations in Concordiasi is smaller than that provided by satellite radiance and wind observations, although the average error reduction per-observation is much larger for dropsondes compared to satellite data. For the dropsonde observations, both temperature and wind data have more impact when they are closer to the pole, with temperature information contributing most at low levels while wind information dominates at high levels (<400 hPa). On a per-observation basis, however, both wind and temperature have larger impact closer to the surface (lower troposphere). This corresponds to areas where there are very few other competing observations, mainly because of the difficulty of using satellite radiance information close to the surface, especially over high terrain.