ISDA 2018

Poster Presentations

Part I
Mon, Tue

Session 1: Convective-scale data assimilation

1.1 GPS Slant Delay Assimilation in COSMO-DE

Main Author: Michael Bender
Institution: Deutscher Wetterdienst, Offenbach, Germany
Co-Authors: Klaus Stephan, Christoph Schraff, Roland Potthast

GPS slant delays provide information about the atmospheric state along each individual satellite receiver axis. In regions with dense GPS ground networks a large number of slant delays is available which scan the atmosphere from different angles and with a high temporal resolution. The data of more than 300 GPS stations in Germany are processed by the GFZ in Potsdam which provides about 3000 slant delays per epoch and more than 70000 delays per hour. These slant delays can be assimilated into the regional numerical weather model COSMO-DE which is operated by the German Weather Service (DWD). The observations are assimilated in a hourly cycle using a local ensemble transform Kalman filter (LETKF) with an ensemble size of 40 members.

The results of some slant delay assimilation experiments will be presented. Slant delays can be assimilated with a local filter only if each slant is located at a certain position. As the slant delay is integrated along the whole signal path it is not obvious where to locate it. The results of different localization strategies combined with different localization radii will be compared.

1.2 Impact of global data on WRF-3DVAR for heavy snowfall simulations over the region of 2018 Pyeongchang Olympic and Paralympic Winter Games

Main Author: Wonsu Kim
Institution: Korea Institute of Science and Technology Information
Co-Authors: Ji-Sun Kang, Minsu Joh

We are participating in International Collaborative Experiments for Pyeongchang 2018 Olympic and Paralympic winter games (ICE-POP 2018) project. This project is supported by World Meteorological Organization (WMO) World Weather Research Program (WWRP) and allows us to better understand winter storm and snowfall over the mountainous area (around Pyeongchang in South Korea) with intensive observing network during 2018 winter games. Here, we plan to examine the impact of NCAR Model for Prediction Across Scales (MPAS) global data on a regional model WRF simulation. Thus, we have compared results between heavy snowfall simulations of WRF using NCAR MPAS global data and NCEP FNL global data as boundary/initial conditions, respectively. Results with MPAS data show comparable performance to those with NCEP FNL data in terms of simulation performance of accumulated snowfall distribution and snowstorm development process. In addition, we have generated background error covariance matrix by NMC methods with each global data and then have performed data assimilation using WRF-3DVAR for the heavy snowfall cases. Those experiments will tell us potential for MPAS predictability that influences on convective scale NWP modeling.

1.3 Impact of wind profile observations on the forecast of the nocturnal boundary layer

Main Author: Tobias Finn
Institution: Universität Hamburg, Germany; Universität Bonn, Germany
Co-Authors: Felix Ament, Gernot Geppert

Ground-based wind profile observations for the lower troposphere have an emerging potential for the forecast of the atmospheric nocturnal boundary layer (NBL), e.g. by upcoming wind lidars. In this study, we examine the observation impact of single tall tower wind observations on the forecast of the NBL. Further, we use a sub-kilometre COSMO setup for the greater area of Hamburg together with the KENDA-LETKF system. We use observation system experiments for three test cases with different stable NBLs. Over all analyses, we revealed a positive impact of the wind observations on the wind speed at analysis time, while the forecast error for the background was increased by chance compared to a control run. A further analysis of the cases showed that the impact of the assimilation disappears after four hours lead time. Also, the analysis displayed that only one of the three NBLs was correctly modelled by COSMO. In one test case, a measured phenomenon was completely missed by all model realisations, which indicates that the model has problems to represent the processes leading to this feature. During the phenomenon, the forecast error was increased compared to the control run, and the forecast could not further improved by additional assimilation of wind observations. This shows that the LETKF cannot counter-balance missing processes within a model with only a limited set of observations. Also, the results show further that the model is more important than the data assimilation for the modelling of the NBL. Nevertheless, in the other two test cases the model error for the wind speed and the potential temperature was decreased by data assimilation such that we proved the positive impact of wind observations on the forecast of the NBL.

1.4 SINFONY - Development of a new seamless prediction system for very short range convective-scale forecasting at DWD

Main Author: Ulrich Blahak
Institution: DWD, Frankfurter Str. 135, Offenbach
Co-Authors: Roland Potthast, Axel Seifert, Alberto De Lozar, Liselotte Bach, Lisa Neef, Elisabeth Bauernschubert, Christian Welzbacher, Kathrin Wapler, Manuel Werner

Additional Co-authors: Rafael Posada, Martin Rempel, Michael Hoff, Markus Junk, Markus Schultze, Kathrin Feige

At DWD a strategic long-term development for the future Seamless INtegrated FOrecastiNg sYstem SINFONY has been started by implementing a pilot project for the next 4 years. The aim is to develop and install a system for ensemble-based storm-scale forecasting from observation time up to +6 h / +12 h forecasts, that integrates classical Nowcasting techniques with numerical ensemble forecasts in a more or less seamless way. The focus of the pilot project is on severe summertime convective events. Up to now, for the first 1-2 h the storm-scale forecasting relies mostly on observation-based nowcasting products, whereas convection-allowing ensemble NWP (COSMO-DE-EPS) is only able to reach/outperform the quality of nowcasting at later times. New NWP forecasts are started only every 3 h and after a rather long cut-off time to wait for incoming observational data. Moreover, nowcasting and ensemble NWP are treated as two separate and independent methods, and there are few common products available for the forecasters. The goal of SINFONY is to narrow down these gaps, on the one hand by enhancements to both nowcasting and NWP separately and on the other hand by mutual information exchange and combination, to further enhance the quality of both. One important component is the assimilation of high-resolution observational data. We consider in particular: - 3D-radar-data (native observations as well as nowcast "objects") - Meteosat SEVIRI IR and VIS satellite data - Lightning flash densities Based on that, a Rapid Update Cycle (RUC) ensemble on the km-scale (ICON-LAM) with hourly updates, 40 members and advanced model physics (2-moment microphysics including hail, 3D-turbulence) is envisaged.

The poster will give a broader overview on the project. It complements presentations of C. Welzbacher, L. Bach and A. DeLozar.

1.5 Assimilation of IASI radiance in the KMA local model

Main Author: Hee-Jung Kang
Institution: Numerical Modeling Center/KMA
Co-Authors: Eunhee Lee, Seungwoo Lee, Yong Hee Lee

The KMA has been running the high resolution model system named as Local Data Assimilation and Prediction System (LDAPS) based on the Unified Model to predict severe weather such as heavy rainfall. The domain of LDAPS is centered on the Korea Peninsula, and the horizontal resolution of LDAPS is a 1.5 - 4 km. Conventional observation (surface, sonde and aircraft), radar and satellite data (scatwind, ground GNSS and AMSU-B) are assimilated in LDAPS. The satellite data have limitations in providing the information with high vertical resolution. The aim of this work is to improve the precipitation forecast accuracy by assimilating IASI radiance with high spectral resolution in LDAPS. The bias correction of the satellite radiance is necessary to improve the forecast performance, but there are few studies related to bias correction on the convective scale model. Although a variational bias correction scheme (VarBC) is known to be effective, a static bias correction scheme based on the Harris and Kelly scheme (2001) is utilized because LDAPS uses 3DVAR data assimilation scheme. The bias correction coefficients for each IASI channel are calculated from the LDAPS during a year to consider the seasonal variation of bias. The impact of the bias correction coefficients from LDAPS is compared to that of the bias correction coefficients from the global model. The preliminary results for optimal IASI assimilation in LDAPS will be shown.

1.6 Relevance of climatological background error statistics for meso-scale data assimilation

Main Author: Jelena Bojarova
Institution: FoU , SMHI, Norrköping, Sweden
Co-Authors: Nils Gustafsson

The number of observations for initialisation of NWP models is several orders of magnitude smaller than the number of model state variables. Background error statistics that contain information on spatial scales of forecast errors and on balances valid between different model state variables are used as an a-priori information to constrain the model state initialisation. Although it was early recognised that the ideal background error statistics need to be flow-dependent, the climatological background error are still playing important role at operational weather services. In this study we analyse the properties of the climatological background error statistics derived from different input ensembles (downscaling of global ensemble, high-resolution EDA, high-resolution BRAND) and investigate the relevance of the background error statistics on different scales performing data assimilation for convection-permitting high-resolution HARMONIE forecasting system.

Session 2: Radar data assimilation and nowcasting

2.1 Impact of Assimilate Doppler Radar Data on Numerical Weather Prediction Model in UAE Territory.

Main Author: Hebatallah Alsakaji
Institution: Mathematical Sciences, United Arab Emirates University, AlAin, UAE
Co-Authors: Fathalla Rihan, Taha Alhosary

Numerical Weather Prediction (NWP) is a technique used to produce an objective forecast for the weather. The desirable forecast is achieved by solving a set of governing equations of variables that governs the evolution of the atmosphere. In order for the problem to be mathematically well posed, the governing equations need to be solved under accurate corresponding initial and boundary conditions. To derive these initial conditions the need of Data Assimilation (DA) has an important role. A Data Assimilation systems combine all available information on the atmosphere to obtain an estimate of atmospheric conditions valid at a prescribed analysis time. Precipitation is one of the most pertinent parameters in the NWP, Doppler radar observations of precipitation are perfect database for Data Assimilation, because of their special properties in determining the spatial evolution of the amount of rain. Latent Heat Nudging (LHN) is a Data Assimilation scheme for the rainfall rates derived from radar reflectivity data, The radar data assimilated with LHN is processed by a coherent quality control in order to have a positive impact in the NWP. This work is a first assessment of utilizing Doppler Radar reflectivity in COSMO-UAE model by LHN scheme, LHN is successfully provides the correct position and amount of the precipitation and matches the model prediction closely to the observed one. Key Words: Latent Heat Nudging, governing equations, Data Assimilation, Radar reflectivity, COSMO-UAE.

2.2 Impact of the observational error in the assimilation of radar reflectivity volumes

Main Author: Thomas Gastaldo
Institution: University of Bologna and Arpae (Regional Agency for Prevention, Environment and Energy of Emilia-Romagna, Italy)
Co-Authors: Virginia Poli, Chiara Marsigli, Tiziana Paccagnella, Pier Paolo Alberoni

At Arpae, the HydroMeteorological Service of Emilia-Romagna Region (Italy), it is operational an ensemble data assimilation system at the convection permitting scale (KENDA), based on the LETKF scheme. The system has been been developed for the Consortium for Small scale Modeling (COSMO) model and, in the current set-up, it is used to assimilate only conventional observations. To fully exploit the potential of KENDA, non conventional data have to be employed. In particular, at Arpae are on-going tests to evaluate the impact of the assimilation of reflectivity volumes from the Italian radar network. A set of experiments shows that a crucial role in determining the quality of the analysis is played by the observational error. This is influenced by three sources: instrumental error, representativity errors and observation operator errors. Since none of these are known, the choice of its value is not straightforward. To estimate the observational error, a diagnostic based on statistical averages of observations-minus-background and observations-minus-analysis residuals is used. This is perfomed separately for each radar since the Italian radar network is inhomogeneous both in the acquisition strategy and from an instrumental point of view. Results both in the assimilation and in the forecast cycle are presented.

2.3 Issues regarding maintaining ensemble spreads, balance, and high-resolution information in rapid-update-cycle radar data assimilation with the LETKF

Main Author: Guo-Yuan Lien
Institution: RIKEN Advanced Institute for Computational Science, Kobe, Japan
Co-Authors: Takemasa Miyoshi

Assimilation of meteorological radar data has been proven useful for analyses and short-range forecasts of convective storms. Ideally, it is desirable to assimilate the radar data at high spatial and temporal resolution, hopefully to extract high-resolution information in the observation. Particularly, running a rapid-update data assimilation cycle is thought to be beneficial in terms that it could avoid the linearization errors of highly nonlinear evolution of convective systems. However, with a typical ensemble data assimilation method, several important issues, such as the maintenance of the ensemble spreads and model balance, could prevent us from effectively using the observation information at high spatial and temporal resolution. At RIKEN, we investigate the feasibility and usefulness of advancing the resolution of radar data assimilation with the LETKF, while we are aware of these concerns. It is very difficult to overcome all problems, but we find several techniques that are practically useful and suitable for the high-resolution convective-scale data assimilation. We will discuss these techniques, such as additive noise, observation number limit, and the deterministic analysis member, with some experimental results that show promise. We will also attempt to suggest a combination of settings of model resolution, data assimilation resolution, ensemble sizes, and update cycle lengths, that could optimize the results given the practical consideration of computational cost.

2.4 Assimilation on the convective scale with an ensemble-based data assimilation system: objects based on radar reflectivities

Main Author: Christian Welzbacher
Institution: Deutscher Wetterdienst (DWD), Offenbach, Germany
Co-Authors: Alberto de Lozar, Roland Potthast, Andreas Rhodin, Ulrich Blahak

At Deutscher Wetterdienst the SINFONY project develops a seamless ensemble prediction system for convective-scale forecasting with forecast ranges from minutes up to 12 hours. The initial focus is on severe summertime convective events with associated hazards such as heavy precipitation, hail and wind gusts.

Currently, depending on the chosen score, predictions of convective cells from Nowcasting systems outperform NWP models for 1 up to 3 hours, while NWP forecasts are superior to Nowcasting predictions after this point in time. We integrate both approaches into a seamless ensemble prediction system.

Objects based on radar reflectivities are operationally used in Nowcasting. We consider object-based methods for the data assimilation of 2D/3D radar reflectivities in NWP, both for core data assimilation reasons and as a tool to exchange information between Nowcasting and NWP.

In March 2017 the Kalman filter for convective-scale data assimilation (KENDA), which has been developed for the Consortium for Small-scale Modelling (COSMO) model, has become operational at DWD (Schraff 2016). This system includes a local ensemble transform Kalman filter (LETKF) and a deterministic analysis based on the Kalman gain for the analysis ensemble mean. KENDA gives the possibility to assimilate an observation type when a corresponding forward operator is available. Therefore KENDA allows us to also assimilate data based on objects in a natural way.

In our research we focus on selected case studies of days with strong convection. We examine constructions of objects based on thresholded 2D radar reflectivity-composites and the assimilation of derived quantities. In particular, we investigate the assimilation of spatially averaged quantities for reflectivities above different thresholds in the spirit of the Fraction Skill Score.

2.5 A Method to Estimate the Uncertainty of Areal Precipitation using Data Assimilation

Main Author: Claire Merker
Institution: MeteoSchweiz, 8058 Zürich-Flughafen, Schweiz
Co-Authors: Felix Ament

Uncertainty information associated with observations is important in order to assess their reliability. It is especially important for areal precipitation information as it is needed, for example, to generate precipitation ensembles for probabilistic hydrological modelling, or to specify accurate error covariance when using precipitation observation for data assimilation into numerical weather prediction models. This work presents a method to estimate spatially and temporally variable uncertainty of an areal precipitation product. The aim of the method is to merge measurements from different sources into a combined precipitation product and to provide an associated dynamic uncertainty estimate. Requirements for this estimate are an accurate representation of the actual uncertainty of the product, an adjustment to additional observations merged into the product through data assimilation, and flow dependency.

The presented method uses data assimilation as a tool to merge precipitation observation. The Local Ensemble Transform Kalman Filter (LETKF) is coupled to an ensemble nowcasting model providing information about the precipitation displacement over time. A continuous nowcasting of a precipitation field and repeated assimilation of additional observations is performed. By this means, the precipitation product and its uncertainty estimate obtained from the nowcasting ensemble evolve consistently in time and become flow-dependent. The method is tested in a proof-of-concept case study with data from an X-band radar network. The results from the case study demonstrate that the provided areal uncertainty estimate outperforms constant benchmark uncertainty values. It enables a more accurate spatial and temporal distribution of uncertainty, increasing the uncertainty estimate for regions where the precipitation product exhibits large errors, and decreasing it where the product has smaller errors.

Session 5: Observation impact and observing strategies

5.1 Investigating the assimilation of MSG/SEVIRI water vapour radiance data to extract wind information with an ensemble kalman filter

Main Author: Marc Pondrom
Institution: Deutscher Wetterdienst (DWD), Offenbach am Main, Germany
Co-Authors: Andreas Rhodin, Christina Köpken-Watts

Satellite observations of water vapour radiances not only contain information about the water vapour distribution in the atmosphere but also on the wind field through the displacement of the water vapour structures. This information can be exploited through the direct tracking of these movements, done e.g. in the derivation of so-called water vapour atmospheric motion vectors, but also in a data assimilation system. For 4Dvar it has been shown that through the so-called tracer effect meaningful wind increments are derived from assimilating a sequence of water vapour radiances benefitting the forecast quality. The current study investigates whether such wind information can also be obtained from an ensemble data assimilation system. The study focuses on the use the clear-sky radiances from the geostationary MSG/SEVIRI instruments in the global EnVAR and LETKF system of DWD. To analyze the behavior of and the results in the ensemble DA, a set of experiments have been conducted for August 2017. First, artificial data from a nature run have been assimilated and background error covariances and analysis increments as well as their dependence on key parameters such as observation and background errors and localization approaches have been studied. In parallel, the system has been prepared for the assimilation of real data, including aspects like data monitoring and bias correction. Results of the nature run experiments and studies involving real data are presented.

5.2 A new Forward Operator for Assimilating Mixing Ratio Profiles in the WRF-DA System

Main Author: Rohit Thundathil
Institution: Institute of Physics and Meteorology, University of Hohenheim, Stuttgart, Germany
Co-Authors: Thomas Schwitalla, Andreas Behrendt, Stephan Adam, Volker Wulfmeyer

New active remote sensing systems for water-vapor profiling such as differential absorption lidar (WVDIAL) and Raman lidar (WVRL) as well as temperature rotational Raman lidar (TRRL) with high accuracy and range-resolution are now operational and commercially available to be operated in networks. For extracting the full information contents of their observations, data assimilation (DA) systems of weather forecast models must contain a suitable forward operator for absolute humidity and/or mixing ratio, respectively. Surprisingly, so far, no corresponding forward operator was available in the WRF-DA system.

In this work, we present the modification and test of an existing forward operator for AIRS retrievals within the WRF-DA for assimilating water-vapor profiles. This advanced operator is applied to high-resolution profiles measured with the WVDIAL and the TRRL of the University of Hohenheim.

The WRF model is configured with 100 levels, with about 30 layers up to 700 hPa and comprises a 2.5-km horizontal resolution over central Europe. Three different experiments were carried out: 1) Control Experiment, 2) TRRL in addition and 3) TRRL and WVDIAL in addition to the Control Experiment. First results of these impact studies will be presented and discussed.

5.3 On the assimilation order of the serial ensemble Kalman filter: A study with the Lorenz-96 model

Main Author: Shunji Kotsuki
Institution: RIKEN Advanced Institute for Computational Science, Kobe, Japan
Co-Authors: Steven Greybush, Takemasa Miyoshi

We usually assume that the assimilation order of the serial ensemble Kalman filter (EnKF) has no significant impact on analysis accuracy. However, Nerger (2015) derived that different assimilation orders result in different analysis states and error covariances if covariance localization is applied in the observation space. This study explores if we can optimize the assimilation order for better analysis accuracy. We examine several assimilation orders with the serial ensemble square root filter using the Lorenz-96 40-variable model. The results show that the small difference due to different assimilation orders could eventually result in a significant difference in analysis accuracy. The analysis is improved significantly by ordering observations from worse to better impacts using the ensemble forecast sensitivity to observations (EFSO), which estimates how much each observation reduces or increases the forecast error. The error reduction by the serial assimilation process of the EFSO-based ordering is similar to that by the experimentally-found best sampled assimilation order.

5.4 Assimilation of GNSS tomography products into WRF using a radio occultation data assimilation operator

Main Author: Natalia Dymarska
Institution: Department of Geodesy and Geoinformation, TU Wien, Vienna, Austria
Co-Authors: Gregor Moeller, Estera Trzcina, Witold Rohm, Robert Weber, Johannes Boehm

The Global Navigation Satellite Systems (GNSS) can be used to determine accurate and high-frequency atmospheric parameters in all-weather conditions. GNSS tomography is a novel technique that takes advantage of slant troposphere observations between GNSS receivers and satellites, traces these signals through the 3D grid of voxels and estimates by an inversion process the refractivity of the water vapour content within each voxel. In the last years, the GNSS tomography development focused on numerical methods to stabilize the solution, which has been achieved to a great extent. Currently, we are facing new challenges and possibilities in the application of GNSS tomography in meteorology. In this study, GNSS tomography was performed by two models (TU Wien, WUELS) within the area of Central Europe during the period of 29 May - 14 June 2013, when heavy precipitation events were observed. Slant Wet Delays (SWD) were calculated based on estimates of Zenith Total Delays (ZTD) and horizontal gradients, provided for 72 GNSS sites by Geodetic Observatory Pecny (GOP). For both models, 3 sets of SWD observations were tested (set1 without compensation for hydrostatic anisotropic effects, set2 with compensation of this effect, set3 cleaned by wet delays outside the inner voxel model). Our previous trials showed that tomography outputs can be assimilated into the Weather Research and Forecasting Data Assimilation model, using its three-dimensional variational assimilation (WRFDA 3DVar) system. In this study, an assimilation of the tomography refractivity in the nested domain over Europe (12- and 36-km resolution) is investigated. This process is enabled by the use of the radio occultation observations operator. However, the assimilation of the tomography products is complex as this procedure requires a proper characterisation of the observation errors. Future improvements to the assimilation method are discussed.

5.5 An Evaluation of implementing 3D-VAR data assimilation on WRF

Main Author: Ming Chun Lam
Institution: Hong Kong University of Science and Technology
Co-Authors: Jimmy Chi-Hung Fung

An initial condition that closely represents the true atmospheric state can minimize errors that propagate into the future, and this could theoretically lead to improvements in the forecast. 3D-VAR allows us to combine concurrent three-dimensional observations at a given time, into the numerical model to optimize their strengths at the same time constraining their weaknesses. This study aims to study the impacts of 3D-VAR on the state of the art Weather Research and Forecasting (WRF) model by evaluating the sensitivity of the initial condition on the forecast as well as the model's limitation. Our observation data are provided by NCEP which includes Surface (METAR, SHIPS, etc.) and Upper-Air (RAOB, ACARS, etc.) data. Previous month's forecasts are used to calculate the Background Error Statistics (BES) via the National Meteorological Center (NMC) method. Our model covers China with an emphasis on Guangdong province has a configuration of three nested domains with a resolution of 27km, 9km, and 3km. The improvements of the initial condition and the forecasts are systematically compared and are quantified in terms of temperature, wind magnitude, sea level pressure and relative humidity. We initialized a 4 days forecast (including 24 hours of spin-up time) every 24 hours for the month of December. Preliminary results show that 3D-VAR provides significant improvements in the initial condition by correcting the bias and the spread of error. The results also show that the improved initial condition provides more significant improvements on the 2nd and 3rd forecast days.

5.6 Assimilation of Reconstructed Radiances from Principal Component compressed Hyperspectral Sounder IASI data in the ICON EnVar

Main Author: Silke May
Institution: DWD (German Meteorological Service), Offenbach a.M., Germany
Co-Authors: Christina Köpken-Watts, Robin Faulwetter, Olaf Stiller, Roland Potthast

Satellite data today is a core ingredient of state-of-the-art systems of numerical weather prediction (NWP). With new hyperspectral infrared atmospheric sounding instruments especially MTG-IRS and IASI-NG the operational data streams face great challenges with increasing amounts of data for processing and assimilation in NWP. Compression methods like principal component analysis (PCA) provide a promising tool to reduce data amount with the capability of noise reduction while maintaining the core information content. The use of reconstructed radiances from principal component scores of the Infrared Atmospheric Sounding Interferometer (IASI) has been investigated in comparison to raw radiances in the operational setup of the ensemble variational data assimilation system (EnVAR) for the global ICON model of Deutscher Wetterdienst (DWD). The processing of reconstructed radiances has been technically implemented and assimilation experiments have been carried out. First monitoring results show a neutral to positive impact on NWP trial. The OBS-FG statistics for IASI are improved. The impact of the observation errors has been investigated.

5.7 ASCAT Wind Superobbing Based on Feature Box

Main Author: Boheng Duan
Institution: Academy of Ocean Science and Engineering, National University of Defense Technology, Changsha, China
Co-Authors: Yan Chen, Pingqiang Wang

Redundant observations impose a computational burden on an operational data assimilation system, and assimilation using high resolution satellite observation data sets at full resolution leads to poorer analyses and forecasts than lower resolution data sets, since high resolution data may introduce correlated error in the assimilation. Thus, it is essential to thin the observations to alleviate these problems. Superobbing like other data thinning methods lowers the effect of correlated error by reducing the data density. Besides, it has the added advantage of reducing the uncorrelated error through averaging. However, thinning method using averaging could lead to the loss of some meteorological features, especially in extreme weather conditions. In this paper, we offer a new superobbing method which takes consideration of the meteorological features. The new method shows very good error characteristic, and the numerical simulation experiment of typhoon "Lionrock" (2016) shows that it produces a positive impact on the analysis and forecast against the traditional superobbing.

5.8 Accelerating assimilation development for new observing systems using EFSO

Main Author: Guo-Yuan Lien
Institution: RIKEN Advanced Institute for Computational Science, Kobe, Japan; Department of Atmospheric and Oceanic Science, University of Maryland, College Park, Maryland, USA

Co-Authors: Daisuke Hotta, Eugenia Kalnay, Takemasa Miyoshi, Tse-Chun Chen

To successfully assimilate data from a new observing system, it is necessary to develop appropriate data selection strategies, assimilating only the generally useful data. This development work is usually done by trial-and-error using observing system experiments, which are very time- and resource-consuming. We propose a new, efficient methodology to accelerate the development using the Ensemble Forecast Sensitivity to Observations (EFSO). First, non-cycled assimilation of the new observation data is conducted to compute EFSO diagnostics for each observation among a large sample. Second, the average EFSO conditionally sampled in terms of various factors is computed. Third, potential data selection criteria are designed based on the non-cycled EFSO statistics, and tested in cycled OSEs to verify the actual assimilation impact. We demonstrate the usefulness of this method with the assimilation of satellite precipitation data. It is shown that the EFSO based method can efficiently suggest data selection criteria that significantly improve the assimilation results.

5.9 Assimilation of GNSS tomography in Near-Real Time mode products into the Weather Research and Forecasting model

Main Author: Estera Trzcina
Institution: Institute of Geodesy and Geoinformatics, Wrocław University of Environmental and Life Sciences, Wrocław, Poland
Co-Authors: Witold Rohm, Jan Kapłon

GNSS tropospheric tomography is a technique that aims to derive 3D distribution of wet refractivity in troposphere using slant GNSS observations (Slant Wet Delay), domain parametrization and the inversion process. This method of GNSS meteorology is one of the most promising since it enables to obtain not the column or slant amount of water vapor, but its 3D distribution. It makes the products of tomography more efficient and convenient to assimilate into NWP models, which is the main potential application for the technique. Although GNSS tomography has been intensively developed last years, the quality of data has not been discussed in terms of assimilation into NWP models. This kind of analysis is essential in further works on the utilization of GNSS tomography products in operational NWP models. This work presents Near-Real Time (NRT) tomographic solution that was performed on the area of Poland using TOMO2 model, in order to verify if tomographic products meet accuracy requirements and could be assimilated into NWP models. The solution was performed using Zenith Total Delays (ZTD) estimated in NRT for ASSG-EUPOS and Leica SmartNet stations by WUELS processing center. Validation based on the Universal Rawinsonde Observation Program (RAOB) data shows the RMSE of the solution is about 7 ppm in the lower troposphere (altitude below 3 km) and not more than 5 ppm in the upper layers. The first attempts of 3D-Var assimilation into Weather Research and Forecasting (WRF) model were made using GPSREF observation operator. Global Forecasting System (GFS) data were used as initial and boundary conditions. The first results show significant impact of GNSS tomography data assimilation on meteorological forecast. Validation of the results will be performed using data from RAOB, values of Integrated Water Vapor (IWV) calculated in WUELS processing center and data from synoptic stations.

5.10 Ensemble Forecast Sensitivity to Observations Verified with Multiple References

Main Author: Shunji Kotsuki
Institution: RIKEN Advanced Institute for Computational Science, Kobe, Japan
Co-Authors: Kenta Kurosawa, Takemasa Miyoshi

It is important to evaluate the impact of assimilated observations on forecast skill in numerical weather prediction (NWP). Several methods have been proposed to estimate the impact of observations with adjoint-based or ensemble-based sensitivity analysis. Most studies evaluate the observational impact using their own analyses as a verification reference. This study investigates the sensitivity of the impact estimates to the choice of the verification reference. We implemented the ensemble-based forecast sensitivity to observation (EFSO) method proposed by Kalnay et al. (2012) with a global atmospheric data assimilation system NICAM-LETKF (Terasaki et al. 2015 and follow-on studies), which comprises the Nonhydrostatic ICosahedral Atmospheric Model (NICAM) and Local Ensemble Transform Kalman Filter (LETKF). We evaluate the impact of observations with the moist total energy norm verified against the NICAM-LETKF's own analysis and the ERA Interim reanalysis. In addition, we implemented an observation-based verification metric proposed by Sommer and Weissmann (2016) and Cardinali (2017). The results suggest that the observational impact be overestimated in 6-h forecasts if the NICAM-LETKF analysis is used for the verification reference. However, no overestimation is observed if we use the ERA-Interim reanalysis and radiosonde observations for the reference. The results imply that the impact of observations at the analysis time would persist in the analysis 6-h later. In the observation-based verification metric, each type of observations mainly contributes to the improvement of the observed variable. For instance, assimilation of the AMSU-A radiances significantly improves the first guess of the AMSU-A radiances at the next assimilation cycle, but this is not necessarily true to other observations. This presentation will include the most recent progress up to the time of the symposium.

5.11 FSOI using an Observation-Based Error Norm for the Met Office UKV model

Main Author: Helen Buttery
Institution: Met Office (UK), FitzRoy Road Exeter EX1 3PB United Kingdom
Co-Authors: Bruce Macpherson

A FSOI (forecast sensitivity to observation impacts) system has been set up to work with the Met Office UKV model (a 1.5-km grid-length LAM over the UK). It uses an observation-based error norm based on a quadratic measure of the fit to SYNOP observations of temperature, relative humidity, 10-m wind speed and log visibility and assesses the 3-hour forecast. A modified version of the UKV trial suite is used with a 7.5-km analysis grid-length in order to reduce instabilities in the linear Perturbation Forecast (PF) model whose adjoint is run as part of the FSOI calculation. Within the 3DVAR data assimilation itself, a standard analysis grid-length of 3km is used. This poster will describe the set-up of the FSOI for use with the Met Office UKV as well as showing the most recent results, including trials on winter and summer periods of 3-4 weeks duration. The version of the UKV system tested so far was the one operational up to August 2015. Results from these trials show that the average total observation impact per run is beneficial over the combination of the two time periods and that SYNOP relative humidity and roadside temperature data show the largest beneficial impacts.

Please note – I will be unable to attend the conference in person (as I will be in the late stages of pregnancy), but a colleague (also attending the conference to present their own work) will present this poster on my behalf.

5.12 Ensemble Sensitivity Analysis - The potential impact of observed quantities on convective precipitation forecast

Main Author: Stefan Geiss
Institution: Hans-Ertel-Centre for Weather Research, Data Assimilation Branch, LMU Munich, Germany
Co-Authors: Martin Weissmann, Takemasa Miyoshi

Potentially, many observations are available for regional data assimilation that are not or just partially exploited yet: high-resolution 3D radar observations, cloud-affected satellite observations, new observing systems (e.g. MW profilers) and community observations (e.g. smart phone pressure sensors). However, little knowledge exists on which variables are most important on which temporal and spatial scales. To examine these issues, Ensemble Sensitivity Analysis (ESA) is applied to several 1000-member ensemble forecasts of convective summertime precipitation in Germany. The 1000-member ensemble forecasts were initialized every six hour from 00 UTC 28 May to 06 UTC 30 May 2016. This very high sample offers new capabilities, especially to examine the potential impact of observed and observable quantities and their potential impact time on precipitation forecast. It is shown that the potential impact of pressure is highest, followed by wind and temperature at all levels and humidity at upper levels. A medium impact is found for humidity at lower levels and less impact of cloud and precipitation quantities. However, highest sensitivities are observed on smaller scales (10 km – 100 km) for humidity and temperature inside the boundary layer, cloud quantities and precipitation. For the evaluation of the methodology the 1000-member ensemble provides an unique opportunity to evaluate the methodology through comparison of the results using the full ensemble to results for using limited subsets of the ensemble. It is demonstrated that a 100-member ensemble shows similar time dependencies like a 1000-member ensemble does.

Session 6: Representation of model error and parameter estimation

6.1 Additive Covariance Inflation in an operational, convective-scale NWP Ensemble Kalman Filter Assimilation System

Main Author: Daniel Leuenberger
Institution: Numerical Weather Prediction, MeteoSwiss, Zürich, Switzerland
Co-Authors: Claire Merker

Ensemble Kalman Filter data assimilation for Numerical Weather Prediction (NWP) applications typically needs some sort of covariance inflation to account for model errors and to ensure that the observations are given enough weight in the update step. The MeteoSwiss operational, convective-scale COSMO-LETKF-based ensemble data assimilation system uses adaptive multiplicative covariance inflation, relaxation to prior perturbations (RTPP) and perturbations of soil moisture in the update step and stochastic perturbations of physical tendencies (SPPT) in the forecast step of the analysis cycle. Spread-skill inspection has shown that especially in winter periods, the ensemble is still under-dispersive, i.e. resulting in too little spread and not enough weight given to the observations. Therefore, an additional covariance inflation based on the climatological B-matrix of the global ICON model of Deutscher Wetterdienst has been tested in assimilation experiments. In this contribution we show results of these experiments and compare analyses and forecasts with and without additive inflation. We further investigate the structure of these climatological perturbations and compare them with flow-dependent variances and covariances of the data assimilation ensemble.

6.2 On the use of Ensemble Singular Vectors (ESVs) as additive inflation for LETKF implemented to a global NWP model

Main Author: Seoleun Shin
Institution: System Configuration Team, KIAPS, Seoul, Korea

It is challenging to selectively represent structures of dynamically growing errors in background states under system uncertainties such as sampling and model errors. In our previous study, it was shown that we can reduce analysis errors by using Ensemble Singular Vectors (ESVs) as additive inflation in the Local Ensemble Transform Kalman Filter (LEKTF) framework implemented to a global NWP model on the cubed-sphere. The reduction was especially significant when we assume that the forecast model is imperfect in Observing System Simulation Experiment (OSSE), and when we test for real data assimilation. The improvement of the LETKF performance is related to the ability of ESVs in capturing fast-growing error modes selectively. It means that we can confine analysis increments in dynamically unstable subspace. In this talk, we focus more on advantages in the use of ESVs as additive inflation in the context of forecast sensitivity to initial conditions. The increase in the accuracy of analysis by using ESVs in LETKF results in forecasts with reduced error for all leading time. It will be also discussed on the use of ESVs in a hybrid-4DEnVar data assimilation system.

6.3 Data Assimilation for a New Stochastic Shallow Water Model

Main Author: Oana Lang
Institution: Department of Mathematics, Imperial College London, UK

We investigate a data assimilation problem via a new Stochastic Rotating Shallow Water (SRSW) model and using real observations corresponding to the temperature, pressure and velocity vector fields. Data corresponds to a layer of Earth's atmosphere between 30 and 60 degrees north latitude and is collected using commercial aircraft. Although Earth's climate system is mostly represented by largescale patterns, it is known that specific smallscale physical mechanisms have a strong impact on the largescale phenomena. Therefore, the smallscale processes must be represented properly. The SRSW model addresses this issue. It models the evolution of a twodimensional rotating shallow water system via a stochastic partial differential equation. The deterministic part of the SPDE consists of a classical rotating shallow water equation while the stochastic part involves a transport type noise which is representative when studying turbulence from a fluid dynamics standpoint.

6.4 A flexible additive inflation scheme for treating model error in ensemble Kalman filters

Main Author: Matthias Sommer
Institution: Hans Ertel Centre for Weather Research, LMU
Co-Authors: Tijana Janjic

Data assimilation algorithms require an accurate estimate of the uncertainty of the prior (background) field that cannot be adequately represented by the ensemble of numerical model simulations. Partially, this is due to the sampling error that arises from the use of a small number of ensemble members to represent the background error covariance. It is also partially a consequence of the fact that the geophysical model does not represent its own error. Several mechanisms have been introduced so far to alleviate the detrimental effects of misrepresented ensemble covariances, allowing for the successful implementation of ensemble data assimilation techniques for atmospheric dynamics. One of the established approaches is additive inflation, which consists in perturbing each ensemble member with a sample from a given distribution. This results in a fixed rank of the effective model error covariance matrix. In this work, a more flexible approach is introduced where the model error samples are treated as additional synthetic ensemble members, which are used in the update step of data assimilation but are not forecasted. This way, the rank of the model error covariance matrix can be chosen independently of the ensemble. The effect of this altered additive inflation method on the performance of the filter is analyzed here in an idealized experiment. It is shown that the additional synthetic ensemble members can make it feasible to achieve convergence in an otherwise divergent parameter setting of data assimilation. The use of this method also allows for a less stringent localization radius.

6.5 On the estimation of the diagonal of background covariance in transform space

Main Author: Kryštof Eben
Institution: Institute of Computer Science, The Czech Academy of Sciences, Prague, Czech Rep.
Co-Authors: Marie Turčičová, Jan Mandel

One of the standard approaches to modeling background covariance in atmospheric data assimilation lies in transforming the control variables to another space, most often spectral, such as Fourier or wavelet space. Since it is expected that the transform makes the coefficients in the spectral expansion approximately independent, a common practice is to estimate the covariance in the transform space by the diagonal of the sample covariance matrix, which may be noisy if the sample size is small. Even though the assumption of independence of transform coefficients may be inadequate, a diagonal approximation of background covariance matrix may be required to make the computations feasible.

We investigate the case when the field of transform coefficients may be approximated by a Gaussian Markov random field. Starting from models for the inverse covariance (precision) matrix, we use the known recursive formulas for estimation of the diagonal of the background covariance from the precision matrix. Imposing constraints on the precision matrix also results in smoothing the diagonal. We illustrate the method and its performance on generated sample fields and on fields coming from a WRF model simulation.

10.1 Visualization of the Ensemble Kalman Filter

Main Author: Kai Sdeo
Institution: Heidelberg University, Germany
Co-Authors: Ole Klein, Filip Sadlo

We present a novel visualization technique to analyze the processes involved in data assimilation. In our current analysis, we focus on the ensemble Kalman filter and its interplay between observations and the underlying simulation model, with the long-term goal of supporting the modeling, operation, and development of data assimilation techniques in general. We exemplify the utility of our approach based on the Lorenz system and simple Navier-Stokes solutions.

Part II
Wed, Thu, Fri

Session 3: Assimilation of cloud-affected satellite observations

3.1 Assimilating all-sky SEVIRI infrared brightness temperatures using the KENDA ensemble data assimilation system

Main Author: Axel Hutt
Institution: Referat FE12 - Datenassimilation , Deutscher Wetterdienst, Offenbach
Co-Authors: Hendrik Reich, Robin Faulwetter, Andreas Rhodin, Martin Weissmann, Christoph Schraff, Roland Potthast

Infrared brightness temperatures (BTs) from geostationary satellites provide detailed information about the cloud distributions. More effective use of this information in modern data assimilation systems has the potential to greatly improve the forecast accuracy for high impact weather events by producing a more accurate initial state in sensitive regions. Specifically water vapor tends to be one of the least accurate variables in initialization datasets due to a lack of in situ observations. In this presentation, we discuss results from ongoing efforts to assimilate clear and cloudy sky water vapour channel brightness temperatures from the SEVIRI sensor onboard the MSG satellite in the Kilometer Scale Ensemble Data Assimilation (KENDA) system. The spatial domain of the COSMO model considered in this study covers most of central Europe with 2.8 km resolution, with observations assimilated once per hour. Efforts are underway to develop correction methods of the bias and the variance of first-guess departures that can effectively remove the bias from both clear and cloudy sky observations. We present first guess departure statistics of BTs classified corresponding to a recently developed cloud impact measure. In addition, we show the impact of SEVIRI water vapour channel BT on temperature, wind and relative humidity during a cycled 4-week data assimilation experiment in summer 2014.

3.2 GNSS Reflectometry wind speeds: Retrieval approach and rain error characterization

Main Author: Milad Asgarimehr
Institution: German research centre for geosceinces, GFZ
Co-Authors: Jens Wickert, Sebastian Reich

Considering potentials of GNSS Reflectometry winds for improving storm-scale predictions, a wind speed model for GNSS data is proposed with a comparable performance to ASCAT and other scatterometers. In addition, the first evaluation of GNSS reflectometry wind seeds during rain events

is carried out. This study is conducted by assessing TDS-1 winds and using buoys observations and the collocated combined microwave-IR estimates of the Tropical Rainfall Measuring Mission (TRMM). An acceptable root mean square error and bias of 2.7 m/s and 0.4 m/s are reported in a rain-free area, respectively. These values are degraded to 3.6 m/s and 0.6 m/s during rain events. The contribution of atmospheric attenuation is investigated simulating the Doppler delay maps and the attenuated power due to precipitation. It is demonstrated that the atmospheric attenuation does not affect rain retrievals significantly. In extreme conditions, at an elevation angle and a rain rate of 20 degrees and 12 mm/h, respectively, the contribution of rain attenuation to wind speed biases cannot be larger than 0.5 m/s. Statistical analysis of TDS-1/TRMM/buoys data demonstrates the effects of altered roughness due to the raindrops hitting the ocean surface. These effects are also observed using the European Centre for Medium-range Weather Forecasts (ECMWF) winds as an additional reference dataset. It is shown that rain splash effects increase the water waves at wind speeds up to 9 m/s. At higher wind speeds, the damping effect calms the ocean in turn. Consequently, these rain effects result in over/underestimation of the surface winds with respect to the buoys and ECMWF measurements, which is not considered in conventional GNSS scatterometry. As a result, rain effects on real GNSS L-band scatterometry data is demonstrated for the first time.

Session 4: Advances in methodology and non-Gaussian approaches

4.1 Kernel embedding of maps for Bayesian inference: The variational mapping particle filter

Main Author: Manuel Pulido
Institution: Department of Meteorology, University of Reading, UK
Co-Authors: Peter Jan Van Leeuwen

In this work, a novel particle filter is introduced which aims to an efficient sampling of high-dimensional state spaces considering a limited number of particles. The filter is based on variational importance sampling. Particles are mapped from the proposal to the posterior density using the principles of optimal transport. The Kullback-Leibler divergence between the posterior density and the proposal divergence is optimized using variational principles. A key ingredient of the mapping is that the transformations are embedded in a reproducing kernel Hilbert space which constrains the dimensions of the space for the optimal transport to the number of particles. Gradient information of the Kullback-Leibler divergence allows a quick convergence using well known gradient-based optimization algorithms from machine learning, adadelta and adam, which do not require cost function calculations. Evaluation of the method and comparison with a SIR filter is conducted as a proof-of-concept in the Lorenz-63 system. No resampling is required even for long recursive implementations. The number of effective particles remains close to the total number of particles in all the recursion. Hence, the mapping particle filter does not suffer from sample impoverishment.

4.2 Improved assimilation of rain via Hybrid particle-Kalman filtering

Main Author: Walter Acevedo
Institution: German Meteorological Service (DWD), Offenbach, Germany
Co-Authors: Sebastian Reich, Roland Potthast

Recent increases in spatial and time resolutions as well ensemble size, has raised awareness of the non-Gaussianity of atmospheric states. This poses an important challenge to prediction centers as the current operational data assimilation (DA) systems still rely heavily on Gaussian assumptions. A particularly problematic variable is precipitation, whose intrinsic non-negative nature can be easily violated by Gaussian DA techniques, such as the EnKF. In our study, we investigate the performance of the Local Ensemble Transform Particle Kalman Filter (LETPKF) applied to atmospheric models. This hybrid methodology utilizes the Local Ensemble Transform Kalman Filter (LETKF) and the Local Ensemble Transform Particle Filter (LETPF) sequentially, and applies localization techniques consistently to both filters. We demonstrate numerically that for moderate ensemble sizes, the LETPKF outperforms both LETKF and LETPF. Moreover, our hybrid approach reduces considerably the amount of negative rain artificially introduced during the analysis steps, which is related to the reduction of negative weights in the LETKF update.

4.3 EFSR: Ensemble Forecast Sensitivity to Observation Error Covariance

Main Author: Daisuke Hotta
Institution: Meteorological Research Institute, Japan Meteorological Agency, Tsukuba, Japan
Co-Authors: Eugenia Kalnay, Yoichiro Ota, Takemasa Miyoshi

Data assimilation (DA) methods require an estimate of observation error covariance (R) as an external parameter that typically is tuned in a subjective manner. To facilitate objective and systematic tuning of R within the context of Ensemble Kalman Filtering, we introduce a method to estimate how forecast errors would be changed by increasing or decreasing each element of R, without a need for the adjoint of the model and the DA system, by combining the adjoint-based R-sensitivity diagnostics of Daescu (2008) with the technique employed by Kalnay et al. (2012) to derive Ensemble Forecast Sensitivity to Observations (EFSO). The proposed method, termed EFSR, is shown to be able to detect and adaptively correct miss-specified R through a series of toy-model experiments using the Lorenz '96 model. It is then applied to a quasi-operational global DA system of the National Centers for Environmental Prediction to provide guidance on how to tune the R. A sensitivity experiment in which the prescribed observation error variances for four selected observation types were scaled by 0.9 or 1.1 following the EFSR guidance, however, resulted in forecast improvement that is not statistically significant. This can be explained by the smallness of the perturbation given to the R. An iterative on-line approach to improve on this limitation is proposed. Nevertheless, the sensitivity experiment did show that the EFSO impacts from each observation type were increased by the EFSR-guided tuning of R.

4.4 Ultra Rapid Data Assimilation based on Ensemble Filters

Main Author: Zoi Paschalidi
Institution: German Weather Service (DWD)
Co-Authors: Christian A. Welzbacher , Walter Acevedo, Roland Potthast

The increasing need of improved weather forecast and weather warnings in specific fields of human activities, combined with the ever-growing availability of continuous high resolved atmospheric measurement data, reveal the limits of the current operational data assimilation methods, regarding speed and flexibility. Thus, the current work proposes an ultra-rapid data assimilation (URDA) method. As neither a full numerical model nor a full grown data assimilation system is used, the URDA method updates the ensemble forecast with high speed and low cost. The URDA is developed on the ensemble transformation matrix given by an Ensemble Kalman filter, employing a reduced version of the state variables adapted to given observation data. It is shown that for linear systems and observation operators, the ultra-rapid assimilation and forecasting is equivalent to a full ensemble Kalman filter step. For nonlinear systems this is no longer the case, however, quite convincing results are obtained, even when rather strong nonlinearities are part of the assimilation interval under consideration. The evaluation not only of a full forecast system but also of a reduced data one, underlines the practical interest of the URDA method when the focus is on the forecast of some layers or part of the state space.

4.5 Gain form of the Ensemble Transform Kalman Filter and its relevance to satellite data assimilation with model space ensemble covariance locali

Main Author: Craig Bishop
Institution: Naval Research Laboratory
Co-Authors: Jeffrey Whitaker, Lili Lei

To ameliorate sub-optimality in ensemble data assimilation, methods have been introduced that involve expanding the ensemble size. Such expansions can incorporate model space covariance localization and/or estimates of climatological or model error covariances. Model space covariance localization in the vertical overcomes problematic aspects of ensemble based satellite data assimilation. In the case of the Ensemble Transform Kalman Filter (ETKF), the expanded ensemble size associated with vertical covariance localization would also enable the simultaneous update of entire vertical columns of model variables from hyperspectral and multi-spectral satellite sounders. However, if the original formulation of the ETKF were applied to an expanded ensemble, it would produce an analysis ensemble that was the same size as the expanded forecast ensemble. This article describes a variation on the ETKF called the Gain ETKF (GETKF) that takes advantage of covariances from the expanded ensemble, while producing an analysis ensemble that has the required size of the unexpanded forecast ensemble. The approach also yields an inflation factor that depends on the localization length scale that causes the GETKF to perform differently to an EnSRF using the same expanded ensemble. Experimentation described herein shows that the GETKF outperforms a range of alternative ETKF based solutions to the aforementioned problems. In cycling data assimilation experiments with a newly developed storm-track version of the Lorenz 96 model, the GETKF analysis Root Mean Square Error (RMSE) matches EnSRF RMSE at shorter than optimal localization length scales but is superior in that it yields smaller RMSE for longer localization length scales.

4.6 Data assimilation and the inevitable state dependence of the error variance of unbiased observations of bounded variables

Main Author: Craig Bishop
Institution: Naval Research Laboratory
The specification of the variance of the distribution of error prone observations of a variable given the true value of that variable is fundamental to all data assimilation schemes. Operational data assimilation methods like the Ensemble Kalman Filter (EnKF) or 4DVar do not accommodate state dependent observation error variances. The inevitability of the state dependence of the variance of errors in observations is made clear by proving that the variance of the error of unbiased observations of bounded variables must tend to zero as the true value of the variable approaches the bound. Three strategies for dealing with state dependent observation error variances in DA schemes that are not designed for them are considered in the context of a univariate model. We let the observation error variance be equal to either (i) the mean of the distribution of observation error variances associated with the data assimilation scheme's prior distribution of truth, or (ii) the observation error variance that would occur if the unknown truth was equal to the average of the ensemble mean and the observed value, or (iii) the true observation error variance associated with the (unknown) true state. Simple univariate data assimilation experiments are

used to show that strategy (iii) is the worst of these approaches and that the best approach is strategy (i). In addition, it is shown that a recently developed Gamma, Inverse-Gamma and Gaussian (GIGG) variation on the EnKF that explicitly accounts for the state dependence of observation error variances near physical bounds outperforms all of the aforementioned strategies.

4.7 Model Error Covariance Matrix Modelling and Decomposition in Particle Filters

Main Author: Yan Chen
Institution: Academy of Ocean Science and Engineering, National University of Defense Technology, Changsha 410073, China
Co-Authors: Boheng Duan, Pinqiang Wang

A modified spectral decomposition method is presented for factorizing localized modelled model error covariance matrix, which is the most important part for the operational implementation of the particle filters with proposal density. Localization of model error covariance matrix may introduce unreasonable negative variances, leading to an indefinite matrix. Hence, it has always been failed to get a real square root of localized model error covariance matrix through Cholesky fractorization, symmetric square root factorization or spectral decomposition. There is an ad hoc method which can directly give the factorization but underestimates the correlation between adjacent grid points. The new method introduced has the ability to eliminate the negative variances. Different model error parameterizations combined with different decomposition approaches are explored with the implicit equal-weights particle filter (IEWPF) scheme. Results of the experiments show that the modified spectral decomposition method is better than simply double using the correlation matrix, which makes the operational implementation of the particle filters become feasible. The new method with IEWPF scheme is also compared with that of the equivalent-weights particle filter(EWPF) scheme and the ensemble adjustment Kalman filter(EAKF). The IEWPF and EWPF outperform the EAKF with the new spectral decomposition method of model error covariance, which shows the great potential of the particle filters for operational usage. The performances of IEWPF and EWPF illustrated in the experiments are depending on the model error covariance matrix modelling methods we choose.

4.8 Bayesian estimation of the observation-error covariance matrix in ensemble-based filters

Main Author: Genta Ueno
Institution: The Institute of Statistical Mathematics, Tokyo, Japan
We develop a Bayesian technique for estimating the parameters in the observation-noise covariance matrix Rt for ensemble data assimilation. We design a posterior distribution by using the ensemble-approximated likelihood and a Wishart prior distribution and present an iterative algorithm for parameter estimation. The temporal smoothness of Rt can be controlled by an adequate choice of two parameters of the prior distribution, the covariance matrix S and the number of degrees of freedom ν. The ν parameter can be estimated by maximizing the marginal likelihood. The present formalism can handle cases in which the number of data points or data positions varies with time, the former of which is exemplified in the experiments. We present an application to a coupled atmosphere–ocean model under each of the following assumptions: Rt is a scalar multiple of a fixed matrix (Rt=αtΣ, where αt is the scalar parameter and Σ is the fixed matrix), Rt is diagonal, Rt has fixed eigenvectors or Rt has no specific structure. We verify that the proposed algorithm works well and that only a limited number of iterations are necessary. When Rt has one of the structures mentioned above, by assuming S to be the previous estimate we obtain a Bayesian estimate of Rt that varies smoothly in time compared with the maximum-likelihood estimate. When Rt has no specific structure, we need to regularize S to maintain the positive-definiteness. Through twin experiments, we find that the best estimate of Rt is, in general, obtained by a combination of structure-free Rt and tapered S using decorrelation lengths of half the size of the model ocean basin. From experiments using real observations, we find that the estimates of the structured Rt lead to overfitting of the data compared with the structure-free Rt.

4.9 Parametric and Non-parametric Frameworks for Integrating Satellite Remotely Sensed Products into the System States via Various Filtering Schemes

Main Author: Mehdi Khaki
Institution: Spatial Sciences, Curtin University, Perth, Australia
The increased number of observations from satellite remote sensing is providing a unique opportunity for improving our understanding of the Earth's physical processes. These observations can be used to constrain the performance of land hydrological model through data assimilation techniques. However, due to the huge amount of data and associated complex noise structures, powerful data integration schemes are required to merge the observations with high dimensional system states. Two different data assimilation frameworks of parametric and non-parametric (data driven) using various filtering techniques are tested to assess their performances in constraining system states using the Gravity Recovery And Climate Experiment (GRACE) terrestrial water storage (TWS) and soil moisture products from the Advanced Microwave Scanning Radiometer - Earth Observing System (AMSR-E) and Soil Moisture and Ocean Salinity (SMOS). Contrary to a standard assimilation method, the non-parametric approach does not require an explicit knowledge of the dynamical model and computationally can be less demanding. Non-

parametric approaches have been recently applied in hydrological studies, suggesting promising performances comparable to a standard assimilation system. The implemented filters include ensemble Kalman filter (EnKF) and a deterministic form of EnKF, the square root analysis (SQRA), and particle filter. These filters are applied in both frameworks of parametric using the World-Wide Water Resources Assessment (W3RA) model and newly developed non-parametric based on Kalman-Takens method. This technique takes advantage of the delay coordinate method to reconstruct the nonlinear dynamics of the studied system within a Kalman filtering framework.

4.10 The Local Ensemble Tangent Linear Model - Accelerated with order Reduction

Main Author: Craig Bishop
Institution: Marine Meteorology Division, Naval Research Laboratory, Monterey
Co-Authors: Joanna Pelc

A leading Data Assimilation (DA) technique in meteorology is 4DVAR which relies on the Tangent Linear Model (TLM) of the non-linear model and its adjoint. The difficulty of building and maintaining traditional TLMs and adjoints of coupled ocean-wave-atmosphere-etc models is daunting. On the other hand, coupled model ensemble forecasts are readily available. Here, we show how a previously described ensemble based method for generating TLMs can be accelerated via a rank reduction method that uses a principle component reduction of a climatology of Local TLMs. The resulting Local Ensemble TLM Accelerated with order Reduction (LETLM-AR) features a low rank projection of some local influence region containing all the variables that could possibly influence the time evolution of some target variable(s) near the center of the region. We prove that high accuracy is guaranteed provided that (i) the ensemble perturbations are governed by linear dynamics, and (ii) the number of ensemble members exceeds the number of retained eigenvectors required to explain a high fraction of the climatological variance of LETLMs. The LETLM-AR approach is faster than the LETLM approach for two distinct reasons. First, key matrix inversions are speeded by the cube of the ratio of the number of variables in the local influence volume divided by the number of retained eigenvectors. Second, the required ensemble size is reduced to just a few members larger than the maximum number of eigenvectors retained for any model grid point. The approach is illustrated with the aid of a simple coupled model. In the case examined, an LETLM-AR is obtained whose accuracy is very close to the original LETLM but it only requires 14 ensemble members instead of 28 ensemble members and the cost of the matrix inversions is reduced by 1-2 orders of magnitude depending on the model level.

4.11 Using lagged covariances to assimilate RAPID data

Main Author: Chris Thomas
Institution: Department of Meteorology, University of Reading, Reading, UK
Co-Authors: Keith Haines, Irene Polo, Jon Robson, Drew Peterson

We present an assimilation of the observations of the AMOC made by the RAPID array at 26°N in the Atlantic Ocean. Previous studies have shown that the AMOC is robustly sensitive to density anomalies in the Labrador Sea which occur at a lead time of several years. The RAPID data are assimilated into a high-resolution (0.25°) global NEMO-CICE model which also assimilates other data as part of a reanalysis. Assimilating the data using a standard variational procedure with a multi-year time window would be impractical in such a system; instead, the aim is to use robust covariance information to make earlier increments without the use of an adjoint. Using a novel methodology, the lagged data are assimilated on top of the trajectory produced by an initial (standard) sequential 3DVar assimilation. The methodology has previously been developed and tested using a idealised simulation study (Thomas and Haines (2017)). The earlier use of AMOC assimilation increments should give better continuity to the AMOC and the heat transports, making the model more useful for initialising coupled forecasts.

4.12 KISTI ensemble data assimilation system implemented to K-MPAS

Main Author: JI-SUN KANG
Institution: Korea Institute of Science and Technology Information
Co-Authors: MINSU JOH

The Korea Institute of Science and Technology Information (KISTI) has been collaborated with the National Center for Atmospheric Research (NCAR) to develop a next generation global NWP model, the MPAS (Model for Prediction Across Scales; Skamarock et al., 2012), in order to improve typhoon track prediction. The version of MPAS optimized for typhoon track prediction over East Asia is referred to as K-MPAS. In addition to the development of the new NWP model, KISTI has started implementing the LETKF (Local Ensemble Transform Kalman Filter; Hunt et al., 2007) data assimilation system. Due to defining features of K-MPAS grids, unstructured centroidal Vornoi hexagonal meshes using a C-grid staggering, we have modified a spatial interpolation of the observation operator. Also, we have made the analysis update MPAS wind defined at the staggered grids in two different ways and compared the results in terms of accuracy and computational cost. Lastly, we will discuss how to well utilize background states with variable resolution of K-MPAS which lets us deal with multi-scale background error statistics.

4.13 Lowering precision in an atmospheric ensemble data assimilation system

Main Author: Sam Hatfield
Institution: Atmospheric, Oceanic and Planetary Physics, University Of Oxford
Co-Authors: Tim Palmer, Peter Düben

We present a new approach to improve the efficiency of data assimilation for numerical weather prediction, by trading numerical precision for computational speed. Data assimilation is inherently uncertain due to the use of relatively long assimilation windows, noisy observations and imperfect models. Therefore, errors incurred from using a precision below double precision may be within the tolerance of the system. Lower precision arithmetic is cheaper, and so by reducing precision in ensemble data assimilation, we can redistribute computational resources towards, for example, a larger ensemble size. Our study is motivated by recent developments in the use of single precision arithmetic in weather forecasting models.

We will present results on how lowering numerical precision affects the performance of an ensemble data assimilation system, consisting of the SPEEDY intermediate complexity atmospheric model and the local ensemble transform Kalman filter. We measure the assimilation error as we lower the precision of floating point operations in the SPEEDY model from double precision to below single precision. We find that the extent to which precision can be lowered without affecting the quality of analyses depends on the degree of model error: when there is model error, precision is less important. We compare the error due to reducing precision with the errors due to imperfect physics and unresolved scales. We speculate about the computational savings that could be achieved by lowering precision, and how these savings could be reinvested to boost the ensemble size.

Session 7: Ensemble forecasting and predictability

7.1 Singular Vector perturbations without linear and adjoint models for the short range

Main Author: Jens Winkler
Institution: Deutscher Wetterdienst, Frankfurter Str. 135, 63067 Offenbach, Germany
Co-Authors: Michael Denhard

The spread-skill relation expresses the ability of an ensemble system to predict forecast uncertainty. Small spreads should be related to situations of high predictability while large predicted spreads should not be useless. Forecast errors may arise from initial condition uncertainties or deficiencies of the model and it is difficult to attribute observed error growth to either of these sources. For more insight to model error properties it would be helpful to know the sensitivities of the model dynamics, i.e. the contributions to error growth from small perturbations in the state space of the model. This kind of error growth is given by the singular vectors of the local Jacobian or more generally for a given optimization time by the eigenvectors of the product of the fundamental tangent linear operator and its adjoint. We show techniques to estimate the spectrum of singular vectors directly from the full non-linear model integrations. We use the Arnoldi iteration, which is quite similar to the Lanczos algorithm used at ECMWF, but latter requires at least some knowledge of the tangent linear operator. We further show how the Broyden method, which is a method for recursively solving non-linear equations, can be adapted for predicting local linear error growth along trajectories in the state space of a model. The Broyden method is an auto adaptive quasi Newton method based on the secant equation. We compare both approximation methods with the true SV for the Lorenz63 and Lorenz96 systems and give an outlook of how to implement these methods in complex NWP forecasting systems.

7.2 The diagonally predominant property of the positive symmetric ensemble transform matrix and its application in ensemble forecast

Main Author: Le Duc
Institution: Japan Agency for Marine-Earth Science and Technology, Yokohama, Japan
Co-Authors: Kazuo Saito, Daisuke Hotta

In the ensemble transform Kalman filter (ETKF), the ensemble transform matrix (ETM) is a matrix that maps background perturbations to analysis perturbations. All valid ETMs are shown to be the square roots of the analysis error covariance in ensemble space P˜^a that preserve the analysis ensemble mean. ETKF chooses the positive symmetric square root T^s of P˜^a as its ETM. This choice is justified by the fact that T^s is the closest matrix to the identity I. Besides this minimum norm property, in practice T^s is observed to have the diagonally predominant property, i.e. the diagonal terms are at least an order of magnitude greater than the off-diagonal terms. To explain the diagonally predominant property, firstly the minimum norm property has been proved. Although ETKF relies on this property to choose its ETM, this property has never been proved in data assimilation literature. The extension of this approach to the diagonal matrix of the form βI with a parameter β reveals that T^s is a sum of a diagonal matrix D and a full matrix P whose norms are proportional, respectively, to the first two moments of the square root of the spectrum of P˜^a. In general cases, these norms are not much different but the fact that the number of non-zero elements of P is the square of ensemble size while that of D is the ensemble size causes the large difference in the orders of elements of P and D. A potential application of this property is to replace T^s by its approximated one given by the diagonal matrix D, which is equivalent to a new method to specify the rescaling factors in the breeding method.

Experiments with real observation shows that the new method outperforms both the breeding and the ensemble transform method in ensemble forecast.

7.3 The Nature and Variability of Ensemble Sensitivity Fields that Diagnose Severe Convection

Main Author: Brian Ancell
Institution: Texas Tech University, Lubbock, TX, USA
Ensemble sensitivity analysis (ESA) is a statistical technique that uses information from an ensemble of forecasts to reveal relationships between chosen forecast metrics and the larger atmospheric state at various forecast times. A number of studies have employed ESA from the perspectives of dynamical interpretation, observation targeting, and ensemble subsetting toward improved probabilistic prediction of high-impact events, mostly at synoptic scales. We tested ESA using convective forecast metrics at the 2016 HWT Spring Forecast Experiment to understand the utility of convective ensemble sensitivity fields in improving forecasts of severe convection and its individual hazards within a real-time ensemble data assimilation/forecasting system. The main purpose of this evaluation was to understand the temporal coherence and general characteristics of convective sensitivity fields, particularly to understand whether they could be used with observations to improve ensemble predictability within an operational framework.

The magnitude and coverage of simulated reflectivity, updraft helicity, and surface wind speed were used as severe convective response functions over a 6-week period, and the sensitivity of these variables to winds, temperatures, geopotential heights, and dew points at different atmospheric levels and at different forecast times are evaluated. The sensitivities are calculated within the Texas Tech real-time ensemble data assimilation/forecasting system, which possesses 42 members that run twice daily to 48-hr forecast time. Here we summarize the findings regarding the nature of the sensitivity fields over the 6-week period and their potential for operational use.

7.4 Sensitive experiments of a radiation fog case inland based on the deterministic and ensemble forecasts of the WRF hybrid ETKF-3DVAR system

Main Author: CHUNYAN SHENG
Institution: Shandong Provincial Meteorological Institute, Jinan, Shandong province, P.R.China
Co-Authors: YUGUANG SHI, SHIJUN LIU

In order to study the key factors of fog numerical forecast, sensitive experiments of a typical radiation fog inland on 8 November 2016 in Shandong province are conducted based on the operational ensemble forecast system in Shandong Provincial Meteorological Bureau. This system is built on the WRF (Weather Research and Forecasting) model and hybrid ETKF-3DVAR system, which includes 12 and 4 km one-way nested deterministic forecast and 24-member ensemble forecasts of 12 km. The sensitive experiments are conducted on the 12 km deterministic forecast and the first 4 ensemble members, including the effect of the assimilation initial fields, lateral boundary conditions and different parameterization schemes on of the fog numerical forecast. Results show that good initial field is the most important for the fog numerical forecast. The hybrid-3DVAR cycle data assimilation can give better initial field for the model, as a result, the fog forecast of the model is improved. In this condition, the effect of the different parameterization schemes of the WRF model is negligible. Relatively the cold start from once hybrid-3DVAR data assimilation can worsen the fog forecast due to the lack of the cloud water information in the initial field. The lateral boundary conditions have less effect on the fog numerical forecast within 12 hours. Suitable parameterization schemes are important for fog numerical forecast when the initial fields are not good enough. According to the experiments in this paper, the suitable boundary-layer scheme for the radiation fog inland is different with that of the sea fog.

Session 8: Data assimilation for land-surface processes and coupled models

8.1 Temperature assimilation on an operational coastal ocean-biogeochemical model: Assessment of weakly and strongly coupled data assimilation

Main Author: Michael Goodliff
Institution: Alfred Weneger Institut, Germany
The effect of satellite sea surface temperature assimilation on the forecast quality of the coastal ocean-biogeochemical model HBM-ERGOM in the North- and Baltic Seas is studied. The HBM-ERGOM model is currently used operationally without data assimilation by the Germany Federal Maritime and Hydrographic Agency (BSH). The model is configured with nested grids with a resolution of 5 km in the North- and Baltic Seas and a resolution of 900 m in the German coastal waters. The biogeochemical model ERGOM contains three phytoplankton groups (Cyanobacteria, Flagellates, Diatoms) and two zooplankton size groups to simulated the biogeochemical cycling in the coastal seas.

To improve the predictions of the HBM-ERGOM model, data assimilation was added by coupling the model to the parallel data assimilation framework (PDAF, http://pdaf.awi.de). The ensemble-based error-subspace transform Kalman filter (ESTKF) is applied for the data assimilation. As a first step to improve the biogeochemical forecasts, before the planned assimilation of ocean colour data products, the impact of assimilating satellite sea surface temperature data is assessed. Two cases are considered. First, the impact of weakly coupled data assimilation. In this case, the assimilation of temperature only directly influences the physical model variables in the analysis step while the biogeochemical fields react dynamically to the changed physical model state during the ensemble forecasts using the coupled model. The second case is the strongly-coupled data assimilation in which next to the physical model fields also the biogeochemical fields are directly updated in the analysis step through the multivariate covariances estimated by the joined physical-biogeochemical ensemble of model states. Here, it is assessed whether these covariances are sufficiently well estimated to result in an improvement of the biogeochemical fields.

8.2 Towards the assimilation of surface sensitive hyperspectral infrared radiances over land

Main Author: Kristin Raykova
Institution: Germany's National Meteorological Service (DWD)
Co-Authors: Christina Köpken-Watts, Andreas Rhodin, Roland Potthast

The assimilation of surface sensitive infrared (IR) radiances over land from hyperspectral satellite sounders like IASI or CrIS represents an active area of research and proves to be a challenging task. Difficulties involve an insufficient knowledge of surface properties like the surface temperature and surface emissivity as well as a reliable detection of cloudy and cloud-free field of views (FOVs). An approach to the retrieval of surface skin temperature and emissivity as well as improving the cloud detection are studied in the framework of DWD's global model ICON. The aim is to assimilate middle troposphere radiances, sensitive to the radiance emitted from the ground, which are not operationally assimilated yet but contain a lot of valuable information for the NWP.

For the retrieval, the surface emissivity spectrum is represented with a principle component (PC) based approach. For specifying the first guess values, we make use of an emissivity atlas provided by the University of Wisconsin (UWIRemis) which also uses a PC representation. The PC coefficients and the skin temperature are part of the state vector as so-called sink variables in our EnVA. For the estimation of the corresponding first guess errors for the PC coefficients we implement and test a maximum likelihood estimate as proposed by Dee and da Silva (1999). We use the same method for estimating the covariance parameters of the FG error of the surface temperature sink variable.

In order to improve the cloud detection, the use of imager data (AVHRR) from the same satellite platform as IASI is studied. AVHRR measures also in the visible spectrum which can complement the infrared observations for cloud detection during the day. This overview poster presents the methods and approaches used, supported by first results.

Session 9: Chemical data assimilation and inverse modelling

9.1 Wind retrieval from 4D-Var assimilation of tracers in moist atmosphere

Main Author: Žiga Zaplotnik
Institution: Faculty of Mathematics and Physics, University of Ljubljana, Ljubljana, Slovenia
Co-Authors: Nedjeljka Žagar

The study addresses the potential of the four-dimensional variational data assimilation (4D-Var) to retrieve the unobserved wind field from the observations of atmospheric tracers (moisture, aerosols) and the mass field through internal model dynamics and the balanced relationships in the background-error term for 4D-Var. The presence of discontinuous and nonlinear moist dynamics makes the wind retrieval from tracers very difficult and susceptible to errors.

The problem of wind retrieval is studied using an intermediate-complexity 4D-Var data assimilation system which simulates nonlinear interactions between the wind, temperature, aerosols and moisture. The description of moist processes includes a simple representation of condensation and the impact of the released latent heat on dynamics. Saturation humidity depends on temperature. Prognostic equation for a single mode aerosol mixing ratio describes the aerosol external processes: advection, diffusion and wet scavenging by precipitation. The OSSE type of experiments are performed in the tropical channel domain. It is shown that wind retrieval from moisture data depends on the spatial density of observations and the frequency of their update in 4D-Var. The former is needed to describe spatial gradients of moisture (as a necessary condition for the wind retrieval), whereas the latter provides information about the advection. If moisture is well observed, 4D-Var can retrieve wind information from moisture observations even in the presence of precipitation. However, in case of aerosol observations in a saturated atmosphere, a small prior error in the wind (or humidity) field can amplify in a positive feedback loop, ruining the analysis. It is necessary to well simulate all other fields (temperature and humidity) affecting the aerosol in order to retrieve useful wind information.

9.2 BEATBOX: Background Error Analysis Testbed with Box Models

Main Author: Christoph Knote
Institution: Meteorological Institute, LMU Munich, Germany
Co-Authors: Jerome Barre, Maximilian Eckl

Assimilating trace gas observations into air quality prediction models is challenging due to the large number of interacting components (emissions, transport, chemistry, aerosols processes, wet and dry deposition) and resulting complexity. Atmospheric gas-phase chemistry alone is a tightly coupled system with highly non-linear interactions between a large number of species, and the effect of assimilating observations of one or a few constituents into the system is often unknown. Reduced dimensionality models are useful exploratory tools in such a situation. Here we present BEATBOX, a testbed for data assimilation methods and error analysis using chemical box models. We employ BEATBOX to investigate the effect of assimilating commonly observed compounds like NO2 or CH2O into tropospheric chemistry mechanisms that are typical for current air quality models. Differences in forecast quality due to data assimilation method and localization are highlighted, and the effect of chemical regimes is explored. Finally we show that BEATBOX can be a useful tool not only to improve forecasts, but also to improve the underlying chemical mechanism.

Session 10: Other topics

10.1 pyenda - The Python Ensemble Data Assimilaton framework

Main Author: Gernot Geppert
Institution: Department of Meteorology, University of Reading, Reading, UK
Co-Authors: Claire Merker

Ensemble data assimilation research most often employs complex software frameworks geared towards high-performance computing or small, purpose-built scripts with limited re-usability. The goal of pyenda - the Python Ensemble Data Assimilation framework - is to combine the flexibility of the former with the simplicity of latter. To achieve this, pyenda includes functionalities for configurable, ensemble-based output, for handling geographical or Cartesian locations, for reading observational data, for changing observational configurations, and for generating synthetic observations.

Forecast models are integrated into pyenda as a Python class. The new forecast model class is derived from an abstract base class to ensure compliance with the framework. The derived class can be a pure Python implementation, it can call C code using Cython, it can call Fortran code using F2PY, or it can rely on MPI-based communication to couple any other model of arbitrary complexity. The ensemble forecasts can be executed in parallel using multiple cores. Data assimilation experiments as well as observational networks are defined in YAML-based text files.

The readability and ease-of-use of Python as well as the range of scientific extension modules facilitate the modification of existing analysis methods or the implementation and testing of new ones.

We will present the design and implementation of pyenda and examples of coupling a model using pure Python, F2PY, and MPI.

10.2 Adopting NCEP's Hybrid 4DEnVar Data Assimilation System to the FV3GFS

Main Author: Rahul Mahajan
Institution: NOAA / NCEP / EMC
Co-Authors: Daryl Kleist, Catherine Thomas, Jeffrey Whitaker, Russ Treadon

Through an National Weather Service (NWS) led community effort, several dynamical cores were evaluated as part of the Next Generation Global Prediction System (NGGPS) and the Finite-Volume Cubed-Sphere Dynamical Core (FV3) was chosen as the replacement of the Global Spectral Model (GSM) for the upcoming fully coupled weather-scale system. It is computationally efficient, conservative, and non-hydrostatic, making it suitable across the many spatio-temporal scales of the weather and climate predictability. The first step towards this unified system is to replace the spectral dynamical core of the Global Forecast System (GFS) with the new dynamical core. The Gridpoint Statistical Interpolation (GSI), which forms the basis of data assimilation for the GFS needs to be adopted to the new dynamical core as well. Development of a prototype FV3GFS system is complete and several components of the legacy GFS system have being incorporated or transitioned into the FV3GFS system including the updates required to the data assimilation system. Several updates are necessary; e.g. addition of use of stochastic physics to represent model uncertainty, initialization of forecasts with the use of an Incremental Analysis Update (IAU), use of a FV3 climatological static covariance matrix are the primary components. In addition to the dynamical core, the cloud microphysics parameterization of Zhao-Carr scheme is being replaced by a more advanced GFDL cloud microphysics to predict the individual hydrometeors. Testing and evaluation of these different components in comparison with the operational GFS version of the model will be presented and a final summary with a review of a realtime pre-operational FV3GFS beta system will be shown.

10.3 On Sequential Multiscale Inversion and Data Assimilation

Main Author: Aamir Nadeem
Institution: University of Goettingen, Institute for Numerical and Applied Mathematics
Federal Urdu University of art science and technology.
Co-Authors: Roland Potthast

Multiscale approaches are very famous for example partial differential equation and various other area of applied fields. The basic idea of multiscale is to decompose the problem into different scales or levels and to use these decompositions either for constructing appropriate approximations or to solve smaller problems on each of these levels, leading to increased stability or increased efficiency. Our aim is sequential multiscale approach in which first we solve problem in larger scale subspace the move to finer scale space. Here we restrict our analysis to one inversion or assimilation step. Our main goal is the understanding of the properties of sequential multiscale inversion and the analysis of convergence when the sequential multiscale approach is iterated. We work out the analysis both for an unregularized and a regularized sequential multiscale inversion. We demonstrate the validity of the iterative sequential multiscale approach by testing the method on an integral equation as it appears for atmospheric temperature retrieval from infrared satellite radiances.

10.4 Study on the identification of mesoscale eddies by taking 4D-VAR method in the South China Sea region

Main Author: Song Li
Institution: College of Meteorology and Oceanology, National University of Defense Technology, Changsha, China
Co-Authors: Weimin Zhang , Shiwei Lin, Pinqiang Wang

A 4-Dimensional Variation Data Assimilation (4D-VAR) experimental system was designed for the South China Sea (SCS) region. And it was taken to study the identification problem of mesoscale eddies in SCS region by assimilating sea level anomaly (SLA) observation. An auto-detective vortex identification algorithm based on SLA was adopted in this study. The data assimilation (DA) experiment shows that the vortex identifying result derived from the posterior field has a better performance than that derived from the prior field. Furthermore, it displays a potential strength for identifying mesoscale eddies by combining DA method. As in conventional vortex identification method, only observation SLA was adopted and it usually has a lower spatial resolution than model settings. And a higher spatial resolution strength owed by the model confirms that a more accurate structures for mesoscale eddies will reveal and it then lead to a better vortex identification result.