## Methodology

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*all times are in UTC*
Breakdown of the equivalence between two common preconditionnings in multi-incremental variational data assimilation

Nicolas Baillot D'etivaux*, Selime Gurol†, Benjamin Ménétrier‡, and Yann Michel§

Abstract

Variational Data Assimilation (DA) schemes are often used to address high dimensional non-linear problems in operational applications in the NWP domain. Because of the high computational cost of such minimization problems, various methods can be applied to improve the convergence at a reasonable numerical cost. One of these methods currently applied in operational DA schemes is the multi-incremental approach that consists in solving a succession of linearized versions of the original non-linear problem in several outer loops, by using well known algorithms (such as Lanczos) to ensure the convergence of the linear problem at the inner loop level, and using the solution of the inner loops to update the problem at each outer loop. In order to save computational cost, the multi-incremental multi-resolution method consists in starting the minimization at a lower resolution than the original one, and increasing it at the outer loop level until the full resolution of the problem. On the other hand, the conditioning of NWP problems is often poor, and one can use preconditioning techniques in order to improve the convergence. We have applied the multi-incremental multi-resolution scheme to a simplified problem in order to study the equivalence of two well known preconditionnings (“full” or “square root”) in such a scheme and also present a new alternative method to update the problem at the outer loop level. We illustrate the differences with the standard method currently used and compare those two methods to the theoretical result. Some equivalence conditions between the updating methods

*Speaker
†Corresponding author: selime.gurol@cerfacs.fr
‡Corresponding author: benjamin.menetrier@irit.fr
§Corresponding author: yann.michel@meteo.fr
and the two preconditionnings are drawn according to the way the resolution change is realised at the outer loop level.

**Keywords:** preconditionning, multi incremental, multi resolution
Impact of assimilating SST vs nudging in an atmosphere ocean coupled model

Kriti Bhargava∗1, Chu-Chun Chang2, Eugenia Kalnay3, Cheng Da4, and Travis Sluka1

1University Corporation for Atmospheric Research – Boulder Colorado, United States
2University of Maryland – Department of Atmospheric and Oceanic Sciences Atlantic Building
 University of Maryland College Park, 20742, United States
3University of Maryland – Department of Atmospheric and Oceanic Sciences Atlantic Building
 University of Maryland College Park, 20742, United States
4University of Maryland – Department of Atmospheric and Oceanic Sciences Atlantic Building
 University of Maryland College Park, 20742, United States

Abstract

In the operational CFS, the surface sea temperature (SST) and surface sea salinity (SSS) at the surface layer is constrained by nudging to the Reynolds OI SST and the annual salinity climatology, respectively. However, this nudging towards SST leads to the alleviation of the SST biases in the CFS analysis. This influences the air-sea flux estimation and leads to a biased forecast. To address this issue, we replace the SST nudging with the Weakly Coupled Data Assimilation of the level 2 (L2) and level 4 (L4) SST products (Canada Meteorological Center). We ran a series of 1-month WCDA and nudging experiments using the CFSv2-LETKF. Our results show that, unlike nudging, WCDA can efficiently correct the existing SST biases and produce a more accurate SST analysis. This also improves the SST 1 to 10 days forecasts. WCDA of SSTs also reduces the RMS error in the atmospheric forecast variables not only at the surface but also at higher model levels.

∗Speaker
Multi-layer Observation Localization for Nonlocal Observations in the LETKF

Cheng Da*,†, Eugenia Kalnay2, and Tse-Chun Chen3

1Department of Atmospheric, and Oceanic Science, University of Maryland, College Park – Atlantic Building, 4254 Stadium Dr. College Park, MD, United States
2Department of Atmospheric and Oceanic Science, University of Maryland, College Park – 4254 Stadium Drive College Park, MD 20742, U.S.A, United States
3Physical Sciences Laboratory, NOAA ESRL – NOAA PSL 325 Broadway Boulder, CO 80305-3328, United States

Abstract

Assimilating nonlocal observations within the Ensemble Kalman Filter is known to be a nontrivial problem. Unlike conventional observations with well-defined locations when observed, nonlocal observations (e.g., radiances, altimeter observations) are intrinsically integrated measurements in space, and thus have no single well-defined observation location. Nevertheless, a single-layer vertical localization (SLVL) approach widely used to handle these nonlocal observations, is to vertically localize them at their weighting function (WF) peaks with symmetric Gaussian-shape localization functions. While this approach can properly assimilate those observations with narrow symmetric WFs, it has difficulties handling observations with broad asymmetric WFs, or multiple WF peaks, which are typical for clear-sky radiance observations from infrared hyperspectral sounders. We developed a multi-layer vertical localization (MLVL) method for nonlocal observations in the Local Ensemble Transform Kalman Filter. The traditional SLVL can be viewed as a particular case of our newly-formulated MLVL. We compared the performance of MLVL and SLVL by assimilating simulated nonlocal observations with a multi-layer quasi-geostrophic model under three scenarios: assimilating nonlocal observations with (a) narrow WFs, (b) broad WFs, and (c) multiple WF peaks. The results show that MLVL has comparable performance as SLVL when assimilating narrow-WF observations, and superior performance than SLVL when assimilating observations with broad WFs or multiple WF peaks.

Keywords: ensemble data assimilation, nonlocal observations, observation localization

*Speaker
†Corresponding author: cda@umd.edu
JEDI application in Assimilation and Evaluation of GTS Synoptic Snow Depth Observations into NCEP Operational FV3GFS System

Jiarni Dong∗1, Daryl Kleist2, Michael Barlarge3, Andy Fox4, Clara Draper5, and Tseganeh Gichamo5

1IMSG at NOAA/NCEP/EMC – 5830 University Research Ct, College Park, MD, United States
2NOAA/NCEP/EMC – 5830 University Research Ct, College Park, MD, United States
3NOAA/NCEP/EMC – 5830 University Research Ct, College Park, MD, United States
4JCSDA/UCAR – 1850 Mitchell Lane, Boulder, CO, 80301, United States
5PSL – 325 Broadway, Boulder, CO, United States

Abstract

The land analysis in the NOAA’s Global Forecast System with FV3 dynamical core (FV3GFS) was conducted with the Global Land Data Assimilation System (GLDAS) using the Noah LSM (Land Surface Model) to evolve land states and to compute surface fluxes. The land states are updated using a “semi-coupled” approach, where these states are generated from a parallel GLDAS driven by observed precipitation and with near-surface forcing from the parent atmospheric data analysis system. However, assimilation of in-situ and remotely-sensed estimates of land-surface states such as soil moisture and snowpack are not supported yet in the operational GLDAS. The Joint Effort for Data assimilation Integration (JEDI) is a unified and versatile data assimilation (DA) system contributing to the Numerical Weather Prediction. NOAA/NCEP working with NOAA/PSL and JCSDA will set up necessary infrastructure to replace GLDAS with JEDI based land data assimilation system for use in initializing the NCEP operational FV3GFS forecast. A set of experiments using 3DVar and JEDI-based OI were conducted to evaluate the impact of assimilating the synoptic snow depth data. The qualities of the GTS synoptic snow depth data were assessed to flag or filter out the poor observations. Optimal parameters are determined by assimilating a single point observation into FV3GFS background setup through specific parameter tuning. We will explore the impact of the snow assimilation on FV3GFS forecasts and compare to the PSL’s offline OI (optimal interpolation) benchmark tests.

Keywords: Land data assimilation, JEDI, based OI, FV3GFS

∗Speaker
A Comparison of Two Local Moment-Matching Nonlinear Filters: Local Particle Filter (LPF) and Local Nonlinear Ensemble Transform Filter (LNETF)

Jie Feng, Xuguang Wang, and Jonathan Poterjoy

1Department of Atmospheric and Oceanic Sciences, Fudan University – Environment Building, Songhu Road 2005, Shanghai, China
2School of Meteorology, University of Oklahoma – 120 David L Boren Blvd., Suite 5900, Norman, OK, United States
3Department of Atmospheric and Oceanic Science, University of Maryland – 4254 Stadium Drive, College Park, MD, United States

Abstract

The local particle filter (LPF) and the local nonlinear ensemble transform filter (LNETF) are two moment-matching nonlinear filters to approximate the classical particle filter (PF). They adopt different strategies to alleviate filter degeneracy. LPF and LNETF assimilate observations in a partially sequential and a simultaneous manner, respectively. In addition, LPF applies the resampling step, whereas LNETF applies the deterministic square root transformation to update particles. Both methods preserve the posterior mean and variance of the PF. LNETF additionally preserves the posterior correlation of the PF for state variables within a local volume. These differences lead to their differing performance in filter stability and posterior moment estimation. LPF and LNETF are systematically compared and analyzed here through a set of experiments with a Lorenz model. Strategies to improve the LNETF are proposed. The original LNETF is inferior to the original LPF in filter stability and analysis accuracy, particularly for small particle numbers. This is attributed to both the localization function and particle update differences. The LNETF localization function imposes a stronger observation impact than the LPF for remote grids and thus is more susceptible to filter degeneracy. The LNETF update causes an overall narrower range of posteriors that excludes true states more frequently. After applying the same localization function as the LPF and additional posterior inflation to the LNETF, the two filters reach similar filter stability and analysis accuracy for all particle numbers. The improved LNETF shows more accurate posterior probability distribution but slightly worse spatial correlation of posteriors than the LPF.

Keywords: Bayesian methods Filtering techniques
Updating and Testing the Snow Data Assimilation in the Unified Forecast System (UFS) Land surface model Noah

Tseganeh Z Gichamo*† and Clara Draper

1CIRES/NOAA ESRL PSL – 325 Broadway, Boulder, CO, United States
2NOAA, ESRL, PSL – 325 Broadway, Boulder, CO, United States

Abstract

Within the NOAA National Weather Service Unified Forecast System (UFS), land processes are simulated by Noah land surface model (LSM). Currently, snow depth and snow cover observations are assimilated into the Noah model using rule-based approaches to update the snow states on a daily time step using the Air Force Weather Agency (AFWA) gridded snow depth analysis product (SNODEP) and snow cover data from NOAA/NESDIS (National Oceanic and Atmospheric Administration’s National Environmental Satellite, Data, and Information Service) Interactive Multi-sensor Snow and Ice Mapping System (IMS). While the approach used at NCEP improved the forecasts over its predecessors, it now needs updating. Other global forecast centers use more advanced data assimilation approaches, compared to the one at the NCEP UFS, to assimilate ground observations of snow depth and snow cover data. In this study, we updated the snow data assimilation in UFS by implementing the 2D Optimal Interpolation (OI) method to assimilate daily snow depth observations from the Global Hydrologic Climatology Network (GHCN) and the NESDIS IMS snow cover data. The data assimilation scheme employed here is based on ECMWF’s implementation, although we have made some changes to suit our particular implementation. Evaluation of the new OI DA in UFS shows marginal improvement of snow depth and significant increase in snow cover skills. The improved snow cover leads to reduced error in near surface air temperature. Following a successful demonstration of these improvements, the OI will be transitioned into operational use at NCEP.

Keywords: Unified Forecasting System (UFS), Snow data assimilation, Optimal Interpolation (OI) DA, IMS, GHCN, Daily.

*Speaker
†Corresponding author: Tseganeh.Gichamo@noaa.gov
Continuum Covariance Propagation for Understanding Variance Loss in Advective Systems

Shay Gilpin, Tomoko Matsuo, and Stephen E. Cohn

1Department of Applied Mathematics, University of Colorado Boulder – University of Colorado, 526 UCB Boulder, CO 80309-0526, United States
2Ann and H.J. Smead Department of Aerospace Engineering Sciences, University of Colorado Boulder – 3775 Discovery Drive, CCAR 429 UCB University of Colorado Boulder, CO 80303-0429, United States

Abstract

At the heart of modern data assimilation schemes is covariance propagation. Loss of variance experienced in large-scale applications such as numerical weather prediction is problematic, and the development of auxiliary methods to mitigate this issue is an active research area. The focus of this work is to understand the root causes of variance loss and show that for advective dynamics, the covariance propagation by itself typically causes significant, spurious loss of variance, even at full rank. To demonstrate this, we first study continuum covariance propagation by analyzing the covariance evolution equation for advective dynamics. The behavior of this evolution equation changes abruptly as the correlation length tends to zero, for example in the vicinity of sharp gradients in the advection field. This happens because the diagonal of the kernel of the covariance operator is a characteristic surface for advective dynamics. Our numerical experiments then confirm that the variance lost during numerical propagation greatly exceeds that due to numerical dissipation alone. The variance loss is driven primarily by inaccurate variance propagation resulting from standard, full-rank covariance propagation schemes, which have difficulty capturing the abrupt change in dynamics as the correlation length tends to zero. These results suggest that developing local covariance propagation methods may prove useful in ameliorating the variance loss observed in data assimilation schemes.

Keywords: variance loss, covariance propagation, advective systems

*Speaker

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A novel regional reanalysis of dust aerosols

Enza Di Tomaso1, Jeronimo Escribano1, Sara Basart1, Paul Ginoux2, Francesca Macchia1, Francesca Barnaba3, Francesco Benincasa1, Pierre-Antoine Bretonnière1, Arnau Buñuel1, Miguel Castrillo1, Paola Formenti4, Maria Gonçalves1, Oriol Jorba1, Martina Klose5, Lucia Mona6, Gilbert Montanyé1, Michail Mytilinaios6, Vincenzo Obiso7, Miriam Olid1, Nick Schutgens8, Athanasios Votsis9,10, Ernest Werner11, and Carlos Pérez García-Pando1,12

1Barcelona Supercomputing Center (BSC) – Torre Girona c/ Jordi Girona, 31, 08034 Barcelona, Spain
2NOAA Geophysical Fluid Dynamics Laboratory – Princeton University, Forrestal Campus, 201 Forrestal Road, Princeton, NJ 08540-6649, United States
3CNR Institute of Atmospheric Sciences and Climate – -, Italy
4Laboratoire Imagerie et Systèmes d’Acquisition – Commissariat à l’énergie atomique et aux énergies alternatives : DRT/DTBS/STD/LISA – -, France
5Karlsruhe Institute of Technology (KIT), Institut für Meteorologie und Klimaforschung – Troposphärenforschung – Karlsruhe, Germany
6Consiglio Nazionale delle Ricerche-Istituto di Metodologie per l’Analisi Ambientale (CNR-IMAA) – -, Italy
7NASA Goddard Institute for Space Studies – 2880 Broadway, New York, NY 10025, United States
8Department of Earth Science, Vrije Universiteit Amsterdam – 1081 HV Amsterdam, Netherlands
9University of Twente, Department of Governance and Technology for Sustainability (BMS-CSTM) – -, Netherlands
10Finnish Meteorological Institute – Erik Palmenin aukio 1, P.O. Box 503, 00 101 Helsinki, Finland
11Agencia Estatal de Meteorología – Madrid, Spain
12Institució Catalana de Recerca i Estudis Avançats – Passeig Lluís Companys 23, 08010 Barcelona, Spain

Abstract

We present a regional reanalysis of dust aerosols which has been recently released by the Barcelona Supercomputing Center for a 10-year period and at the high spatial resolution of 0.1°. The reanalysis has been obtained by ingesting an innovative dust optical depth data set, derived from the MODIS Deep Blue products, in the dust module of the MONARCH atmospheric model by means of a LETKF with a four-dimensional extension. We outline the different modelling, observational and assimilation aspects related with the production of the reanalysis, whose unprecedented high resolution has required the use of advanced computing and workflow strategies, which are also described.

By providing an accurate and complete reconstruction of dust for a recent decade, this novel
reanalysis yields useful information to support operational early warning systems, as well as the development and refinement of environmental monitoring and mitigation strategies, in line with the mission of the WMO Sand and Dust Storm Warning Advisory and Assessment System.

Acknowledgment
The authors acknowledge co-funding from the H2020 ERA-net ERA4CS (GA 690462) as part of the project DustClim; HPC access from PRACE (eDUST/eFRAGMENT1/eFRAGMENT2) and RES (AECT-2020-3-0013/AECT-2019-3-0001/AECT-2020-1-0007). Carlos Pérez García-Pando acknowledges support from the ERC (GA 773051) and the AXA Research Fund.

**Keywords:** regional reanalysis, mineral dust, aerosol optical depth, high resolution, ensemble data assimilation.
An Adaptive R Estimator with a Storm-Scale Particle Filter

Takuya Kawabata\textsuperscript{1} and Genta Ueno\textsuperscript{2}

\textsuperscript{1}Meteorological Research Institute [Tsukuba] – 1-1 Nagamine, Tsukuba, Ibaraki 305-0052, Japan
\textsuperscript{2}The Institute of Statistical Mathematics – 10-3 Midori-cho, Tachikawa, Tokyo, Japan

Abstract

Ueno and Nakamura (2016) proposes the adaptive R estimator (ARE) with an ensemble Kalman filter for estimating flow-dependent observational errors in sea-surface-height observations by TOPEX/POSEIDON. ARE is a Bayesian estimator with a likelihood estimated with an ensemble and a prior R with a Wishart distribution. Kawabata and Ueno (2020) have developed a storm-scale particle filter with the JMA nonhydrostatic model, and ARE has been implemented in the filter, called as NHM-RPF (NonHydrostatic Model R-estimating Particle Filter). NHM-RPF succeeded to represent non Gaussianity of initiation and development stages of a Cb with 1000 ensemble and showed the origin of the non Gaussianity was the updraft on the top of the boundary layer in an OSSE. For this success, ARE played an essential role in stable filtering. In the case that ARE was switched off, NHM-RPF illustrated worse scores than the no data assimilation experiment. The estimated R seemed to be reasonable and to follow the stages and course of the Cb. In this presentation, we will discuss detailed impacts of ARE in the experiment and also show another case with actual observations.

Keywords: storm, scale, particle filter, observation error estimator
Local Ensemble Transform Kalman Filter
Experiments with Hybrid Background Error
Covariance: A Case with an Intermediate AGCM

Shunji Kotsuki\textsuperscript{1} and Craig Bishop\textsuperscript{2}

\textsuperscript{1}CEReS, Chiba University – Yayoi-Cho 1-33, Inage-Ku, Chiba 263-8522, Japan
\textsuperscript{2}U. Melbourne – Parkville VIC 3010, Australia

Abstract

Recent operational numerical weather prediction (NWP) systems have achieved significant forecast improvements by using hybrid background error covariance (HBEC) that linearly combines climatological and ensemble-based error covariance. The HBEC has been used mainly in variational data assimilation systems to use the flow-dependent error covariance in addition to static error covariance. This study explores using the HBEC within the local ensemble transform Kalman filter (LETKF). The standard LETKF approximates the error covariance matrix by sample estimates using the flow-dependent ensemble perturbations. This study followed the Kretchmer et al. (2015)’s approach and implemented the HBEC by adding a collection of climatological perturbations to the forecast ensemble mean to boost the rank of the background error covariance. For HBEC, we propose a new localization (Z-localization) that attenuates ensemble perturbation instead of inflating observation error variance (R-inflation). The Z-localization enables multi-scale localization by applying different localization scales to flow-dependent and climatological perturbations. We tested the HBEC and new localization with an intermediate atmospheric model known as the SPEEDY (Simplified Parameterizations, Primitive Equation Dynamics). Our preliminary results are promising, and the HBEC successfully reduced analysis errors compared to the standard LETKF. This presentation will include the most recent progress up to the time of the symposium.

Keywords: LETKF, hybrid error covariance, localization, multi, scale
Numerical discretization causing error variance loss and the need for inflation

Richard Ménard\textsuperscript{1}, Sergey Skachko\textsuperscript{2}, and Olivier Pannekoucke\textsuperscript{3}

\textsuperscript{1}Environnement et Changement climatique Canada – 2121, route Transcanadienne, Dorval, Québec, Canada
\textsuperscript{2}Environment and Climate Change Canada – Montreal, Canada
\textsuperscript{3}CNRM – Météo-France – Toulouse, France

Abstract

The effects of model discretization errors on the propagation of error covariance are different and more complex than the effect of model discretization errors of a state variable. The analysis is carried out for the advection transport equation, where the continuous (space/time) propagation of the related error covariance function can be written, solved and compared with the discrete model applied on the covariance matrix. The numerical analysis of the problem is carried with a 1D-problem, but is also illustrated with a 3D-chemical transport model used for chemical data assimilation of satellite observations. It is shown that variance loss (compared to the continuous propagation solution) depends on the covariance function itself as well as the numerical discretization scheme. The variance loss is particularly sensitive to the correlation length and model discretization. In a simple first-order discretization an analytical expression is obtained and is used to obtain an analytical expression for inflation. Experiments show that for example that right after an analysis using a dense network of observations (with spatially uncorrelated errors) results in a very significant variance loss, over the observed region. This effect occurs between analysis times during time propagation. With the (variance) inflation scheme, we are able to restore the variance loss at each grid point, at each time steps, during the whole time of integration. The variance inflation scheme applied to an EnKF can be formulated to change the variance spread of the ensemble or directly on the state variables.

Keywords: inflation, discretization error

\textsuperscript{*}Speaker
Assimilation of Nonlinear Observations with the Maximum Likelihood Ensemble Filter

Saori Nakashita*† and Takeshi Enomoto2

1Graduate School of Science, Kyoto University – Kitashirakawa Oiwake-cho, Sakyo-ku, Kyoto, Japan
2Disaster Prevention Research Institute, Kyoto University – Gokasho, Uji, Kyoto, Japan

Abstract

We investigate the performance of the Maximum Likelihood Ensemble Filter (MLEF) in assimilation of nonlinear observations. MLEF is a variational-ensemble data assimilation method, and can treat differentiable or non-differentiable nonlinear observation operators. In this study, we compare MLEF with the Ensemble Transform Kalman Filter (ETKF) in assimilation experiments with a one-dimensional Burgers model. The ETKF analysis with a certain formulation of nonlinear operators diverges when the observation nonlinearity is strong and the observation error is small. This divergence is found to be associated with an extra rank of ensemble perturbation matrix. Optimization in MLEF can improve the analysis to the level comparable to or better than ETKF. In addition, the smaller observation error is, or the stronger observation nonlinearity is, MLEF with the nonlinear operators can assimilate observations more effectively than MLEF with the tangent linear operators. However, the strong nonlinearity hinders convergence. We found that re-evaluation of the Hessian preconditioning matrix can alleviate such poor convergence. These encouraging results indicate that MLEF can incorporate nonlinear effects and evaluate observations appropriately.

Keywords: Variational ensemble method, Nonlinear observations, Optimization

*Speaker
†Corresponding author: nakashita@dpac.dpri.kyoto-u.ac.jp

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A hybrid nonlinear-Kalman ensemble transform filter for data assimilation in systems with different degrees of nonlinearity

Lars Nerger∗1

1 Alfred Wegener Institute – Am Handelshafen 12, 27570 Bremerhaven, Germany

Abstract

A hybrid nonlinear-Kalman ensemble transform filter (LKNETF) algorithm is built by combining the second-order exact particle filter NETF (nonlinear ensemble transform filter) with the local ensemble transform Kalman filter (LETKF). The hybrid filter combines the stability of the LETKF with the nonlinear properties of the NETF to obtain improved assimilation results for small ensemble sizes. Both filter components are localized in a consistent way so that the filter can be applied with high-dimensional models. The degree of filter nonlinearity is defined by a hybrid weight, which shifts the analysis between the LETKF and NETF. Since the NETF is more sensitive to sampling errors than the LETKF, the latter filter should be preferred in linear Gaussian cases. An adaptive hybrid weight can be defined based on the nonlinearity of the system so that the adaptivity yields a good filter performance in both linear and nonlinear situations. In particular the skewness and kurtosis of the ensemble can be applied to quantify the non-Gaussianity. The filter behavior is exemplified based on experiments with the chaotic Lorenz-63 and -96 models, in which the nonlinearity can be controlled by the length of the forecast phase. In these experiments the hybrid filter can yield an error reduction of up to 28% compared to the LETKF.

∗ Speaker
CAFE60v1: The CSIRO Climate retrospective Analysis and Forecast Ensemble system: version 1: System design, model configuration and data assimilation.

Terence O’kane1, Paul Sandery1, Pavel Sakov2, Vassili Kitsios1, Matthew Chamberlain1, Mark Collier3, Russell Fiedler4, Thomas Moore1, Christopher Chapman4, Bernadette Sloyan4, and Richard Matear4

1Terence O’Kane – 3-4 Castray Esplanade, Battery Point 7004, Hobart, Australia
2Bureau of Meteorology, Australia – Docklands, Victoria, Australia
3CSIRO Oceans and Atmosphere – 107-121 Station st, Aspendale, Victoria, Australia
4CSIRO Oceans and Atmosphere – 3-4 Castray Esplanade, Battery Point 7004, Hobart, Australia

Abstract

We detail the system design, model configuration and data assimilation of the CSIRO Climate retrospective Analysis and Forecast Ensemble system: version 1. CAFE60v1 has been designed with the intention of simultaneously generating both initial conditions for multi-year climate forecasts and a large ensemble retrospective analysis of the global climate system from 1960 to present. Strongly coupled data assimilation (SCDA) is implemented via an ensemble transform Kalman filter in order to constrain a general circulation climate model to observations. Satellite (altimetry, sea surface temperature, sea ice concentration) and in-situ ocean temperature and salinity profiles are directly assimilated each month, whereas atmospheric observations are sub-sampled from the JRA-55 atmospheric reanalysis. Strong coupling is implemented via explicit cross domain covariances between ocean, atmosphere, sea ice and ocean biogeochemistry. Atmospheric and surface ocean fields are available at daily resolution and monthly resolution for the land, subsurface ocean and sea ice. The system produces 96 climate trajectories (state estimates) over the most recent six decades as well as a complete data archive of initial conditions potentially enabling individual forecasts for all members each month over the 60 year period. The size of the ensemble and application of strongly coupled data assimilation lead to new insights for future reanalyses.

Keywords: climate reanalysis, decadal prediction

*Speaker
Assimilation of SMAP Brightness Temperature Observations in the GEOS Land-Atmosphere Data Assimilation System

Rolf Reichle*,1, Sara Q. Zhang1,2, Qing Liu1,3, Clara S. Draper4, Jana Kolassa5,6, and Ricardo Todling5

1NASA Goddard Space Flight Center – Greenbelt, MD 20771, United States
2Science Applications International Corporation – Reston, VA 20190, United States
3Science Systems and Applications, Inc. [Lanham] – 10210 Greenbelt Road, Suite 600, Lanham, Maryland 20706, United States
4NOAA Earth System Research Laboratories – Boulder, CO, United States
5NASA Goddard Space Flight Center – Greenbelt, MD 20771, United States
6Science Systems and Applications, Inc. [Lanham] – 10210 Greenbelt Road, Suite 600, Lanham, Maryland 20706, United States

Abstract

Errors in soil moisture adversely impact the modeling of land-atmosphere water and energy fluxes and, consequently, near-surface atmospheric conditions in atmospheric data assimilation systems (ADAS). To mitigate such errors, a land surface analysis is included in many such systems, although not yet in the currently operational NASA Goddard Earth Observing System (GEOS) ADAS. This study investigates the assimilation of L-band brightness temperature (Tb) observations from the Soil Moisture Active Passive (SMAP) mission in the recently developed GEOS weakly-coupled land-atmosphere data assimilation system (LADAS) during summer 2017. The SMAP Tb analysis improves the correlation vs. in situ measurements of LADAS soil moisture by ~0.1-0.26 over that of the ADAS; the unbiased root-mean-square error (ubRMSE) of LADAS soil moisture is reduced by 0.002-0.008 m3 m-3 from that of ADAS. Furthermore, the global average RMSE vs. in situ measurements of LADAS screen-level air specific humidity (q2m) and daily maximum temperature (T2mmax) is reduced by 0.05 g kg-1 and 0.04 K, respectively, from that of ADAS. Regionally, the RMSE of LADAS q2m and T2mmax is improved by up to 0.4 g kg-1 and 0.3 K, respectively. Improvements in LADAS specific humidity extend into the lower atmosphere (below ~700 mb), with relative improvements in q2m bias and ubRMSE of 15-25% and 1-3%, respectively. LADAS air temperature bias slightly increases but ubRMSE is reduced relative to that of ADAS. Finally, the root-mean-square of the LADAS Tb observation-minus-forecast residuals is smaller by ~0.1 K than in a land-only assimilation system, which corroborates the positive impact of the Tb analysis on the modeled land-atmosphere coupling.

Keywords: Land data assimilation, microwave remote sensing, soil moisture, SMAP

*Speaker
†Corresponding author: rolf.reichle@nasa.gov
Towards the assimilation of microwave vegetation optical depth into global land surface models

Samuel Scherrer∗1, Wouter Dorigo1, Zdenko Heyvaert2, Gabrielle De Lannoy2, Alexander Gruber2, Emanuel Büechi1, and Jean-Christophe Calvet3

1Technische Universität Wien – Karlsplatz 13, 1040 Vienna, Austria, Austria
2Catholic University of Leuven - Katholieke Universiteit Leuven – Oude Markt 13 - bus 5005, 3000 Leuven, Belgium
3CNRM (Université de Toulouse, Météo-France, CNRS) – CNRM, Météo-France – 42, Av. G. Coriolis, 31057 Toulouse Cedex 1, France, France

Abstract

Only a few recent studies have considered assimilating microwave vegetation optical depth (VOD) to improve estimates of vegetation states in land surface models (LSMs) with dynamic vegetation. These studies showed that VOD assimilation can improve estimates of GPP, ET, and CO2 concentrations. We intend to assimilate VOD from merged products, as well as from multiple individual passive and active microwave sensors, using the NoahMP and SURFEX-ISBA LSMs. This poses several challenges, in particular developing observation operators for VOD for the different sensors, or characterizing model and observation error structures. We will present various linear and nonlinear approaches to map variables simulated by the models to VOD observations. These will be evaluated with respect to their performance with merged VOD products from the VOD Climate Archive (VODCA) for different bands (Ku/X/C/L), and on single-sensor VOD retrievals from LPRMv6. Additionally, we will assess the added value of including plant water status related variables compared to using only optical vegetation indices as predictor variables for VOD.

Acknowledgements: This work is part of the projects CONSOLIDATION, funded by the Austrian Science Fund (FWF), and the CCN1 CCI+ Soil Moisture Scientific Evolution, funded by ESA.

Keywords: land surface data assimilation, vegetation optical depth

∗Speaker
A variational particle filter

Amit N Subrahmanya∗†, Andrey A Popov† and Adrian Sandu†

1Department of Computer Science at Virginia Tech – 2202 Kraft Drive Blacksburg, VA 24060, United States

Abstract

Particle filters or Sequential Monte Carlo techniques are used in data assimilation for state estimation. Unlike other Kalman-like methods, particle filters work with fewer assumptions and are generic in nature. Standard variational particle techniques involve minimizing the KL Divergence between the prior and a Bayesian posterior via kernel embeddings. However, these methods require rigorous tuning in a high-dimensional setting. In this work, we propose to perform the aforementioned minimization without kernel embeddings. We perform a sequence of transformations to push the particles towards the posterior. With this in mind, we have developed methods for both filtering and smoothing. We have run experiments on Lorenz ’63, Lorenz ’96 and the quasi-geostrophic equations that show promising results qualitatively (rank histogram) and quantitatively (RMSE) when compared to the Mapping Particle Filter, the Ensemble Transform Particle Filter and the Ensemble Kalman Filter.

Keywords: Particle Filters, Variational methods, Particle flows

∗Speaker
†Corresponding author: amitns@vt.edu
Assimilating atmospheric infrasound data to constrain atmospheric winds in a two-dimensional grid

Javier Amezcua*1,2

1University of Reading – Whiteknights, PO Box 217, READING, Berkshire, RG6 6AH, United Kingdom
2National Centre for Earth Observation – University of Reading, United Kingdom

Abstract

Infrasound waves travelling through atmospheric channels are affected by the conditions the encounter in their path. The shift in the backazimuth angle of a wave front detected a reception site depends on the cross-wind it encountered. Estimating the original field from this integrated measurement is an (ill-posed) inverse problem. By using a prior, this can be converted into a Bayesian estimation problem. In this work we use the (ensemble) Kalman filter to tackle this problem. In particular, we provide an illustration of the setup and solution of the problem in a two-dimensional grid, depending on both across-track distance and height, which has not been done in previous works. We use a synthetic setup to discuss the details of the method. We show that one of the effects of along-track averaging (something done in previous studies to simplify the problem) is to overestimate the magnitudes of the analysed values, and propose that this should a source of model error. We also illustrate the process with real data corresponding to nine controlled ammunition explosions that took place in the summer of 2018.

Keywords: ensemble kalman filter, integrated observations, infrasound waves, atmospheric winds

*Speaker
Impact of Ocean Observations on ECMWF Extended-Range Forecasts

Content

In this work, we demonstrate the role of accurate initialisation of ocean conditions on ECMWF coupled forecasts, focussing on the sub-seasonal range. Impact of ocean in-situ observations in the extended-range forecasting system is assessed by carrying out Observing System Experiments (OSEs). Removal of all ocean in-situ observations in the initial conditions leads to significant degradation in the forecasts of ocean surface and subsurface mean state at different lead times from week1 to week4. The negative impact is predominantly contributed by the Argo observing system. Consistent degradation in bias is seen across surface and sub-surface ocean variables over regions such as north Atlantic deep water formation sites, western boundary current regions and tropical Pacific. Changes in the mean state of atmospheric variables is comparatively small but significant in the forecasts of upper atmospheric circulation over tropics and extra tropics. Our results support the need for observations and initialisation of ocean mixed layer for further improving coupled forecasts in the sub-seasonal to seasonal range.

Primary author:  Dr BALAN-SAROJINI, Beena (ECMWF)

Co-authors:  Dr BALMASEDA, Magdalena (ECMWF); VITART, Frederic (ECMWF); ROBERTS, Chris (ECMWF); ZUO, Hao (ECMWF); TIETSCHE, Steffen (ECMWF); Dr MAYER, Michael

Presenter:  Dr BALAN-SAROJINI, Beena (ECMWF)

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Assimilation of Web Camera Derived Estimates of Horizontal Visibility

Jacob Carley∗†1, Michael Matthews2, Matthew Morris3, Manuel Pondeca4, Jenny.colavito@faa.gov Colavito5, and Runhua Yang6

1NOAA Environmental Modeling Center – College Park, MD, United States
2MIT Lincoln Laboratory – Lexington, MA, United States
3SRG at NOAA/Environmental Modeling Center – College Park, MD, United States
4IMSG at NOAA/Environmental Modeling Center – College Park, MD, United States
5Federal Aviation Administration – Washington, DC, United States
6IMSG at NOAA/Environmental Modeling Center (Retired) – College Park, MD, United States

Abstract

Conditions associated with limited horizontal visibility account for a disproportionate number of aviation related accidents in Alaska. This is in part due to the relatively sparse observing network in the region. In order to supplement traditional visibility observations the U.S. Federal Aviation Administration (FAA) maintains a network of high quality web cameras throughout the state. This work explores the potential for deriving automated estimates of horizontal visibility via image processing and assimilating the resulting estimates in NOAA’s Real Time Mesoscale Analysis System. Results suggest that the web camera-derived estimates of visibility are effective for capturing visibilities associated with the most restrictive flight categories. The assimilation of these estimates can improve the resulting analysis. Implications for future studies and operations are discussed.

Keywords: aviation, visibility, web camera, regional, surface analysis, novel observations, RTMA

∗Speaker
†Corresponding author: jacob.carley@noaa.gov
Ensemble Forecast Sensitivity to Observations applied to a regional data assimilation system over Argentina

Gimena Casaretto∗3,2,1, Maria Eugenia Dillon1,2, Yanina García Skabar2, Juan Ruiz4, Maximiliano Sacco2, and Guo-Yuan Lien5

3Departamento de Ciencias de la Atmosfera y los Oceanos – Buenos Aires, Argentina
2National Meteorological Service – Av. Dorrego 4019 C1425GBE, Buenos Aires, Argentina
4Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET) – Avda. Rivadavia 1917 - CP C1033AAJ - Cdad. de Buenos Aires, Argentina
5Central Weather Bureau – 64, Gongyuan Road, Taipei, Taiwan

Abstract

Observations that are assimilated into numerical weather prediction systems are conformed by numerous data sets and the impact of the observations must be objectively evaluated. The Forecast Sensitivity to Observation (FSO) provides an efficient impact evaluation of each observation on forecasts. This study proposes applying the simpler ensemble formulation of FSO (EFSO, Kalnay et al 2012) to the Weather Research and Forecasting model coupled with the Local Ensemble Transform Kalman Filter in Argentina (Dillon et al 2019). The experiment is carried out during 25 days of the intensive observing period of the RELAMPAGO-CACTI field campaign that was conducted during the 2018-2019 austral warm season in the center of Argentina (Nesbitt et al 2021). Analyses were obtained every 6-h with a 20-km resolution, assimilating data from soundings, aircrafts, satellite, AIRS and surface and automatic stations. 6-hour forecast sensitivity is computed for each observation type. The results evidence that wind, temperature and humidity from automatic stations have nearly neutral impact on the forecast skill. Sounding, aircrafts and atmospheric infrared sounder observations present a larger positive impact. Also the spatial distribution of the sensitivity documents the beneficial impact of observations in the forecasts for the central area of Argentina. It is shown that the EFSO method can efficiently suggest data selection criteria.

Keywords: forecast sensitivity, observation, WRF, LETKF

∗Speaker
†Corresponding author: gimenacasaretto@gmail.com
Assimilating Disorganized Crowdsourced Imagery Data for Machine Learning-based Geomorphological Change Detection Research

Thomas Chen∗

1 Academy for Mathematics, Science, and Engineering – 520 W Main Street, Rockaway, NJ 07866, United States

Abstract

As open source data becomes more ubiquitous, the involvement of citizen scientists has increased. The collection of large quantities of relevant data and respective labels through crowdsourcing on online platforms has yielded many exciting opportunities for machine learning applications. In geomorphology, multitemporal imagery, much of which is captured through crowdsourcing, is especially useful for training deep learning models for change detection in landscapes. This is relevant in terms of natural hazards that occur, including endogenous types like volcanoes and neotectonics, exogenous ones such as floods, karst collapses, sedimentation, erosion, tsunamis, and avalanches, as well as climate change or land use-induced hazards like permafrost and desertification. However, a challenge when harnessing crowdsourced imagery is the disorganized and "unclean" fashion in which it often presents itself. Cleaning data prior to training neural network-based computer vision models is key to success in any geomorphology change detection research. We discuss approaches such as manual techniques, image restoration and denoising, and image duplication reduction. The goal is to assimilate a diverse range of data collected from many sources to successfully train machine learning algorithms. In a broader sense, this research has the potential to save lives by detecting possibly destructive and dangerous geomorphological change, and to conserve environments that have been affected severely.

Keywords: crowdsourcing, assimilation, machine learning, geomorphology, computer vision

∗Speaker
Deriving observation impact measures through the FV3-JEDI interface

Fabio Diniz∗†, Ricardo Todling2, Daniel Holdaway3, Francois Vandenberghe4, and Daryl Kleist5

1UCAR Joint Center for Satellite Data Assimilation – 3300 Mitchell Lane, Boulder, CO, 80301, United States
2NASA Goddard Space Flight Center – Greenbelt, MD 20771, United States
3UCAR Joint Center for Satellite Data Assimilation – 3300 Mitchell Lane, Boulder, CO, 80301, United States
4UCAR Joint Center for Satellite Data Assimilation – 3300 Mitchell Lane, Boulder, CO, 80301, United States
5NOAA National Centers for Environmental Prediction – 5830 University Research Court, College Park, MD 20740, United States

Abstract

The Joint Center for Satellite Data Assimilation (JCSDA) and its partners have been interfacing a variety of models to the Joint Effort for Data assimilation Integration (JEDI). These models include the NOAA’s Global Forecast System (GFS) and NASA’s Goddard Earth Observing System (GEOS). Efforts are presently on the way to complete implementation and testing of a full resolution cycled data assimilation for these two models. One feature of interest to be added to the implementation is the capability to evaluate the contribution of the observations to reduce forecast errors using the Forecast Sensitivity-based Observation Impact (FSOI) technique. We have added a preliminary, model agnostic, implementation of FSOI to the Object-Oriented Prediction System (OOPS) layer of JEDI. The present work applies this OOPS capability to generate FSOI for both GEOS and GFS. The presentation will discuss practical aspects of the implementation and provide preliminary results.

Keywords: forecast sensitivity, observation impact

∗Speaker
†Corresponding author: fabiodiniz@ucar.edu
Status of Atmospheric Motion Vectors use in the NCEP GFS data assimilation system

Iliana Genkova∗†, Haixia Liu‡, Catherine Thomas§, Daryl Kleist¶, Jaime Daniels#, Karina Apodaca$, and Dave Santek%

1IMSG – 5830 University Research Ct, College Park, MD 20740, United States
2NOAA/NCEP – 5830 University Research Ct, College Park, MD 20740, United States
3NOAA/NESDIS – 5830 University Research Ct, College Park, MD 20740, United States
4NOAA/AOML – 5830 University Research Ct, College Park, MD 20740, United States
5CIMSS/UWisconsin – 1225 Dayton St, UWisc/SSEC/CIMSS, Madison, WI, United States

Abstract

The Global Observing System’s upper-air observations component has improved with the launch of a number of next generation weather satellites. Advanced Baseline Imager (ABI) - class imagers with surpassing spatial and spectral capabilities are now on board the Himawari and GOES satellites. In addition, the Spinning Enhanced Visible and Infrared Imager (SEVIRI) on board the Meteosat Second Generation (MSG) Meteosat-8/11 has many of the spatial and spectral features as ABI. These technological advancements have led to new algorithm development and improved Atmospheric Motion Vector’s (AMVs) data products from EUMETSAT, JMA and NOAA/NESDIS. New wind products are thoroughly studied, evaluated and tested before inclusion in the NCEP’s Global Data Assimilation System (GDAS) as they become available. We will present results from recent model implementations allowing the use of Meteosat-8 and 11, Himawari-8, Goes-16/17 and S-NPP/NOAA-20 VIIRS winds, preparation for Metop-B/C AVHRR winds, and evaluation of LeoGeo and Aeolus winds. We will illustrate that improved handling of the AMVs leads to the development of a more robust forecasting system.

Keywords: Satellite winds, AMVs, Observations, Data Assimilation

∗Speaker
†Corresponding author: iliana.genkova@noaa.gov
Estimates of radiosonde impact and their implications

Bruce Ingleby

ECMWF – Shinfield Park, Reading, RG2 9AX, United Kingdom

Abstract

The impact of each assimilated data value is estimated in the ECMWF system using Forecast Sensitivity to Observation Impact (FSOI). Aggregated statistics provide useful information on the relative impact of different variables, levels and geographic locations. For radiosondes and aircraft the wind FSOI is more than twice the temperature FSOI and reports in data sparse areas have larger impact than those in data dense areas.

Recent work has shown that the impact of stratospheric radiosonde data north of 45N is much stronger in winter than in summer. This has possible implications for the targets set for radiosondes (numbers of profiles reaching 30 hPa or 10 hPa etc) and should encourage the use of larger balloons in winter - on average balloons burst at lower altitude in winter unless such measures are taken.

Keywords: Radiosondes, FSOI, stratosphere

*Speaker
Assimilation of GK-2A clear sky radiance products in the KIM DA system

Han-Byeol Jeong\textsuperscript{*1}, Hyoung-Wook Chun\textsuperscript{2}, and Jeon-Ho Kang\textsuperscript{1}

\textsuperscript{1}Korea Institute of Atmospheric Prediction Systems (KIAPS) – 4F, 35, Boramae-ro 5-gil, Dongjak-gu, Seoul, South Korea
\textsuperscript{2}Korea Meteorological Administration (KMA) – 61, Yeouidaebang-ro, Dongjak-gu, Seoul, South Korea

Abstract

The Korea Meteorological Administration (KMA)'s operational global numerical weather prediction (NWP) system, named Korea Integrated Model (KIM), was developed by the KIAPS (Korea Institute of Atmospheric Prediction Systems) and it started to run in April 2020. GEO-KOMPSAT-2A (GK-2A, located in 128.2E) Clear Sky Radiance (CSR) data assimilation (DA) system that assimilates 3 water vapor channels has been developed as a part of the KIM DA system. The Advanced Meteorological Imager (AMI) onboard the GK-2A satellite, Korea’s second geostationary satellite, is composed of 16 channels. The GK-2A’s CSR product is defined as the output of the area-averaged brightness temperature for a given pixel in the clear sky area observed by the satellite.

To better understand the products and enhance the quality control for the GK-2A CSR in the KIM Package for Observation Processing (KPOP), we had retrieved the main features of it compare to other CSR products such as Himawari-8 CSR and investigated the impact of its data assimilation. In this study, the quality control process for GK2A CSR will be described. And, preliminary results from the GK2A CSR data assimilation will be examined around South Korea.

Keywords: GK2A, AMI, data assimilation, CSR, KIM, Korea Integrated Model, KIAPS

\textsuperscript{*}Speaker
\textsuperscript{†}Corresponding author: hbjeong@kiaps.org
An Evaluation for Impacts of Ocean Observing System in the NCEP GODAS

Hyun-Chul Lee*† and Daryl Kleist‡

1IMSG at NOAA/NCEP/EMC – National Centers for Environmental Prediction 5830 University Research Court College Park, MD 20740, United States
2NOAA/NCEP/EMC – National Centers for Environmental Prediction 5830 University Research Court College Park, MD 20740, United States

Abstract

The current National Centers for Environmental Prediction (NCEP) Global Ocean Data Assimilation System (GODAS) assimilates in situ profile data from EXpendable BathyThermograph (XBT) and Conductivity Temperature Depth (CTD), stationary fixed moorings, autonomous Argo floats, and remotely sensed sea surface temperature using a variational method of 3D-var in a daily cycle. The ocean model of GODAS is MOM3 with one degree horizontal resolution with 40 vertical levels. With GODAS, these data from ocean observing systems are fundamental to NCEP’s operational efforts not only for monitoring the ocean state but also for forecasting multi-week to seasonal variability in the NCEP Coupled Forecasting System (CFS). In order to evaluate the impact of the observation system in the NCEP operational products, a series of observing system experiments (OSE) of 5-day/10-day cycle runs have been carried out, and the observational innovations and the analysis increments associated with individual ocean observations in NCEP’s GODAS are calculated from the OSE runs. The impact of individual and regional observations, based on Assimilation Impacts of Observing Systems and Forecast Impacts of Observing Systems from the OSE runs, were estimated and applied to monitor the spatio-temporal impacts of ocean observing systems in the current operational NCEP GODAS.

Keywords: evaluation observation impact, Ocean Observing System, NCEP GODAS

*Speaker
†Corresponding author: hyun-chul.lee@noaa.gov
Sea Surface Temperature analysis within the NCEP GFS

Xu Li\textsuperscript{1}, John Derber\textsuperscript{2}, Andrew Collard\textsuperscript{2}, and Daryl Kleist\textsuperscript{3}

\textsuperscript{1}IMSG at EMC/NCEP/NOAA – 5830 University Research Court, College Park, MD 20740, United States
\textsuperscript{2}IMSG at EMC/NCEP/NOAA – 5830 University Research Court, College Park, MD 20740, United States
\textsuperscript{3}NOAA/NCEP – 5830 University Research Ct, College Park, MD 20740, United States

Abstract

The Sea Surface Temperature (SST) analysis within the NCEP GFS, referred to as NSST (Near-Surface Sea Temperature), became operational in July 2017. In the NSST, the SST, with the foundation temperature as the analysis variable, is analysed together with the atmospheric analysis variables, by Grid Statistical Interpolation (GSI), the atmospheric assimilation system in the NCEP GFS. The satellite observations are used as radiances, instead of retrievals, as in other SST stand-alone analysis systems. The background is persistence, but modified with diurnal warming and skin-layer cooling simulated by the NSST model and with a monthly SST climatology constraint.

The NSST has undergone several upgrades since becoming operational in the NCEP GFS. With the initial implementation, it was found that small-scale spatial features are not well resolved and the cloud contamination of the partly clear AVHRR radiance cannot be discriminated well with the available GSI cloud detection scheme. To address these issues, a few NSST updates have been developed and tested with GFSv15.2 and GFSv16 recently. They are: the inclusion of VIIRS radiances, new background error correlation length scales, a smaller thinning box size for AVHRR and VIIRS radiances and exclusion of AVHRR partly-cloudy radiances. Experimental results have shown the NSST analysis can be improved significantly through the aforementioned modifications.

Next steps include the addition of the NSST functionality in the Joint Effort for Data Assimilation Integration (JEDI) system and the use of the NSST in coupled data assimilation in the Unified Forecast System (UFS).

Keywords: Sea Surface Temperature analysis, direct assimilation

\textsuperscript{*}Speaker
\textsuperscript{†}Corresponding author: John.Derber@noaa.gov
\textsuperscript{‡}Corresponding author: Andrew.Collard@noaa.gov
\textsuperscript{§}Corresponding author: daryl.kleist@noaa.gov
Observing System Simulation Experiments in the Brazil Current using SWOT synthetic data with HYCOM+RODAS

Leonardo Pires∗1,2, Janini Pereira1,2,3, Clemente Tanajura1,2,3, Filipe Costa1,2, and Vitor Vidal1

1Oceanographic Modeling and Observation Network (REMO) – Geophysics and Geology Research Center, Federal University of Bahia (CPGG/UFBA), Brazil
2Graduate Program in Geophysics – Geosciences Institute, Federal University of Bahia (UFBA), Salvador, Brazil
3Department of Earth and Environmental Physics – Physics Institute, Federal University of Bahia (UFBA), Salvador, Brazil

Abstract

The assimilation of SWOT altimetry data will play a key role in the understanding of ocean energy and mesoscale processes. In the present work, Observing System Simulation Experiments (OSSEs) were performed with the Hybrid Coordinate Ocean Model + Oceanographic Modeling and Observation Network Data Assimilation System (HYCOM+RODAS) with 1/24° of horizontal resolution and 21 vertical layers. The synthetic data of SST was obtained from a free run using ROMS, the SSH to nadir and SSH type SWOT were obtained from a simulator by Gaultier et al (2017). The objective of the work is to evaluate the impact of assimilating synthetic SWOT altimetry data with HYCOM+RODAS on the Brazil Current kinetic energy (11° - 34° S). Three experiments were carried out to achieve this goal: expt 1.0, assimilating only synthetic SST data; expt 1.1, assimilating synthetic SST and nadir SLA data; and expt 1.2, assimilating synthetic SST, nadir SLA data, and SWOT SLA data. The result of the generation of synthetic SSH data showed very high SWOT errors in the regions of the outer edges of each band of the satellite ground track. However, the system managed to assimilate this data as it was evident in the analysis increment along the SWOT tracks. Mean Kinetic Energy (MKE) and Eddy Kinetic Energy (EKE) fields improved both on the surface and in depth when SWOT synthetic data were assimilated in HYCOM+RODAS. The features in the MKE and EKE fields in expt 1.2 were more similar to those in the ROMS run. The best correlations for the SSH fields, zonal and meridional velocities with respect to ROMS were found in in expt 1.2. RMSE of SST with respect to ROMS in these three experiments was reduced by more than 50% when compared to the control run.

Keywords: Kinetic energy, SAR interferometry, Satellite altimetry, Assimilation system

∗Speaker
†Corresponding author: leo_lp27@hotmail.com
Influence of Snow Representation in Operational Seasonal Prediction Systems

Danny Risto∗†1, Kristina Fröhlich2, and Bodo Ahrens1

1Institute for Atmospheric and Environmental Sciences, Goethe University Frankfurt – Altenhöferallee 1, 60438 Frankfurt/Main, Germany
2Deutscher Wetterdienst – Frankfurter Str. 135 63067 Offenbach, Germany

Abstract

Recent seasonal forecast systems have difficulties predicting temperature over continental regions, whereas for some regions with maritime influence their performance is better. For continental regions, the land surface can become a more important source of predictability on (sub-)seasonal time scales. Snow is a crucial component of the land surface as it stores water and modulates the earth’s radiation budget each winter season. A snow-covered land surface leads to local temperature decreases in the overlying air (snow-albedo effect and high emissivity) and melting snow cools the surface air and contributes to soil moisture and river water. We compare the snow representation in seasonal forecast systems from four European weather/climate services and their performance in predicting snow, temperature and precipitation. The goal is to identify the impact of the snow initialisation and snow modelling from the four forecasts systems. The first results show that the predicted anomalies of 2m temperature over continental regions correlate with reanalyses only for the first forecasted month, whereas anomalies in snow water equivalent can be predicted up to several months. While the biases among the forecast systems differ, the correlation skills are similar for the same variable, with precipitation having the lowest correlation skills. Furthermore, we will investigate the causal relationships between snow and 2m temperature with time-lagged correlation or similar methods.

Keywords: snow, seasonal forecast, seasonal prediction

∗Speaker
†Corresponding author: risto@iau.uni-frankfurt.de
A virtual network of ground-based microwave radiometers for monitoring of atmospheric stability and its potential impact in synergy with hyperspectral satellite observations.

Maria Toporov*1 and Ulrich Löhnert†2

1University of Cologne – Albertus-Magnus-Platz, 50923 Köln, Germany
2University of Cologne – Köln, Germany

Abstract

In this contribution, we show the potential of a network of ground-based MWR to complement observations of the future Infrared Sounder (MTG-IRS) and to provide information on atmospheric stability. The last is described in terms of CAPE and Lifted Index. We present a neural network retrieval of CAPE and LI from simulated IRS and MWR measurements based on the COSMO-REA2 reanalysis as truth. To assess the spatial representativeness of observations of a single ground-based MWR and to estimate the required network density the retrieval is applied to a 150*150km reanalysis domain. The impact of a MWR network was investigated in two ways. First, using spatial statistical interpolation, the fields of CAPE/LI retrieved from IRS observations were merged with the CAPE/LI values from MWR. Within this method, the contribution of ground-based network consisting of a varying number of radiometers was shown to be significant under cloudy conditions. The second approach mimics the assimilation of satellite and ground-based observations in the space of retrieved CAPE/LI fields. Assuming the persistence of atmospheric fields for a period of six hours, the CAPE/LI fields calculated from reanalysis were taken as a first guess in an assimilation step. Observations, represented by CAPE/LI fields obtained from satellite and ground-based measurements with +6 hours delay, were assimilated by spatial interpolation. Within this method, the added value of MWR observations is highly dependent on the current weather situation, cloudiness, and the position of MWR. As the next step, an observing system experiment is planned and will be performed to show the possible benefit of assimilation of ground-based MWR observations into the regional high-resolution ICON model.

Keywords: ground based observations, atmospheric stability, boundary layer, satellite observations, synergy

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*Speaker
†Corresponding author: ulrich.loehnert@uni-koeln.de
Estimating the impact of commercial observations with an Ensemble of Data Assimilations approach

Francois Vandenberghe\textsuperscript{*1}, Hailing Zhang\textsuperscript{2}, Clementine Gas\textsuperscript{3}, and Tom Auligne\textsuperscript{4}

\textsuperscript{1}Joint Center for Satellite Data Assimilation – PO Box 3000, Boulder, CO 80307, United States
\textsuperscript{2}Joint Center for Satellite Data Assimilation – PO Box 3000, Boulder, CO 80307, United States
\textsuperscript{3}Joint Center for Satellite Data Assimilation – PO Box 3000, Boulder, CO 80307, United States
\textsuperscript{4}Joint Center for Satellite Data Assimilation – PO Box 3000, Boulder, CO 80307, United States

Abstract

The assessment of the impact of individual components of the observing system on forecast quality is traditionally conducted through Observing System Experiments (OSE) or Forecast Sensitivity - Observation Impact experiments (FSOI), when the real observations are available, or Observing System Simulation Experiments (OSSE) when observations must be simulated. When an ensemble forecast is available, an alternative approach has been shown to be a good alternative, at least qualitatively. This approach estimates the analysis uncertainty from the spread between the ensemble members. The change in spread between two different ensembles, one with and one without the observing system of interest, provides useful information about the impact of that observing system on forecast accuracy. This method was demonstrated using simulated data from the AEOLUS mission, and later applied at ECMWF with simulated GNSSRO measurements.

Using the JEDI’s Ensemble Data Assimilation function, JCSDA has conducted similar experiments with the GNSSRO commercial data acquired during NOAA Data Order 1 period (Dec. 15 - Jan. 15) using NOAA FV3-GFS operational ensemble 6-hours forecasts. In this preliminary study, we looked at the ensemble spread reduction after analysis and no forecast was performed. The spread reduction resulting from the assimilation of commercial observations can clearly be identified and its magnitude is consistent with spread reductions that have been previously observed at ECMWF with synthetic data. Those preliminary results give confidence that the method provides useful qualitative information about observation impact on analysis accuracy, and we are planning to expand the method as more commercial weather data are available.

Keywords: observation impact, ensemble data assimilation, commercial weather data

\textsuperscript{*}Speaker
Impact of Aircraft High-Density Observations on GFSv16 Tropical Cyclone Forecasts

Xingren Wu∗1, Daryl Kleist2, Vijay Tallapragada2, Fanglin Yang2, and Jason Sippel3

1IMSG at EMC/NCEP/NWS/NOAA – College Park, MD, United States
2NOAA Environmental Modeling Center – College Park, MD, United States
3NOAA/AOML/Hurricane Research Division – Miami, FL, United States

Abstract

High-density observation (HDOB) data are assimilated in the operational Hurricane Weather Research and Forecast (HWRF) model. HDOBs include flight-level wind, temperature, and moisture measurements, and SFMR-derived surface wind speeds from the NOAA P-3, NOAA G-IV and Air Force Reserve Command C-130 aircraft. The assimilation of HDOB data in HWRF showed a considerable forecast benefit for tropical cyclone forecasts. Changes to the NCEP Global Forecast System (GFS) have been driven by the successes in HWRF data assimilation. In this study the NCEP pre-operational GFS version 16 (GFSv16) was used to examine the impact of HDOB data on the GFS forecast for hurricanes. GFSv16 is based on GFS version 15, with the finite volume cubed-sphere dynamical core and microphysics from GFDL. Changes in GFSv16 include increasing the vertical resolution from 64 to 127 levels and moving the model top to 80 km height, improved physics, using a Local Ensemble Kalman Filter with model space localization and linearized observation operator, and employing the 4-Dimensional Incremental Analysis Update technique (4D-IAU) for data assimilation (DA). The experiments to assimilate HDOB data were set up and run using the same GFSv16 pre-operational version for reforecast with a 6-hourly DA cycle, over selected periods with available HDOB data. Track and intensity have been analyzed and compared to the GFSv16 reforecast. Improvements are observed with less track error and an increase in track forecast skill for the Atlantic and West Pacific when the HDOB data are used. For the Eastern Pacific basin, the impact is neutral on the track forecast and there is slight degradation in the intensity. Based on most of the positive impacts, the HDOB was added to GFSv16 for operations.

Keywords: High density observation, Global Forecast System, Data assimilation, Hurricane
Interpreting estimated Observation Error Statistics of Weather Radar Measurements using the ICON-LAM-KENDA System

Yuefei Zeng*, Tijana Janjic, Feng Yuxuan, Ulrich Blahak, Alberto De Lozar, Elisabeth Bauernschubert, Klaus Stephan, and Jinzhong Min

1 Meteorologisches Institut, Ludwig-Maximilians-Universität (LMU) München – Theresienstr. 37, Munich, Germany
2 Meteorologisches Institut, Ludwig-Maximilians-Universität (LMU) München – Theresienstr. 37, Munich, Germany
3 Key Laboratory of Meteorological Disaster of Ministry of Education/Collaborative Innovation Center on Forecast and Evaluation of Meteorological Disasters, Nanjing University of Information Science Technology – Nanjing, China
4 DWD – Frankfurter Str. 135, 63067 Offenbach am Main, Germany
5 Key Laboratory of Meteorological Disaster of Ministry of Education/Collaborative Innovation Center on Forecast and Evaluation of Meteorological Disasters, Nanjing University of Information Science Technology – Nanjing, China

Abstract

Assimilation of weather radar measurements including radar reflectivity and radial wind data has been operational at the Deutscher Wetterdienst, with a diagonal observation error (OE) covariance matrix. For an implementation of a full OE covariance matrix, the statistics of the OE have to be a priori estimated, for which the Desroziers method has been often used. However, the resulted statistics consists of contributions from different error sources and are difficult to interpret.

In this work, we use an approach that is based on samples for truncation error in radar observation space to approximate the representation error due to unresolved scales and processes (RE) and compare its statistics with the OE statistics estimated by the Desroziers method. It is found that the statistics of the RE help the understanding of several important features in the variances and correlation length scales of the OE for both reflectivity and radial wind data and the other error sources from the microphysical scheme, radar observation operator and the superobbing technique may also contribute, for instance, to differences among different elevations and observation types. The statistics presented here can serve as a guideline for selecting which observations to assimilate and for assignment of the OE covariance matrix that can be diagonal or full and correlated.

Keywords: Representation error, Desroziers method, radar data assimilation

*Speaker