Incorporating Flow-dependent Model Errors in Local Ensemble Transform Kalman Filter: Role of Stochastic Back-scatter

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Ensemble forecasting, and data assimilation involves deriving the probability information or uncertainty of the prediction from a set of numerical model forecasts or an ensemble. The uncertainty in the forecast is largely due to unknown initial conditions and parameterization schemes. In the framework of an Ensemble Prediction System (EPS), the initial uncertainty can be tackled by running the model using a set of possible initial conditions (analysis ensemble). On the other hand model uncertainties can be tackled to some extent by introducing "stochastic parameterization" schemes. Apart from the model uncertainties caused by the initial condition and parameterization schemes, numerical models generally tend to over-dissipate near the truncation scale. Shutts (2005) proposed the use of a stochastic kinetic energy backscatter (SKEB) algorithm to compensate for reduced energy up-scaling due to the over-dissipation. It has been shown that random injection of backscatter near the model truncation scale seems to compensate for the absence of inverse cascade (Shutts 2005; Charron, M. et al, 2009).

In the framework of a Local Ensemble Transform Kalman Filter (LETKF) assimilation system, the model error is approximated by an ensemble of model forecasts, and the generated ensemble must be consistent with model errors as seen by LETKF assimilation system. In general the model error is introduced into the LETKF algorithm by introducing random noise to each ensemble member. This random noise should reflect the statistical properties such as the amplitude, spatial distribution, as well as spatial and temporal correlations. Ideally, SKEBS scheme is one of the best candidates to represent model errors since the backscatter scheme reflects errors due to dissipation or damping on the small scales by numerical diffusion etc. One of the main advantages of SKEB is that the scheme accounts for the dissipated Kinetic Energy, and the perturbations are flow dependent. In our GME-EPS experiments, a modified version of the cellular automated SKEB scheme (Shutts, 2005) is used to inject the dissipated kinetic energy back into the model. Our EPS results show backscatter significantly improves the forecast up to 6/7 days if it is used along with random white noise in the LETKF assimilation system. Our results also show there is statistically significant improvement in the GME forecast (without the LETKF data assimilation) up to 4/5 days.

Stochastic Parametrisation and Model Uncertainty in the Lorenz '96 System

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Simple chaotic systems are useful tools for testing possible methods to use in numerical weather simulations due to their transparency and computational cheapness. The Lorenz (1996) toy model of the atmosphere was used in this investigation, which describes a set of coupled large and small scale variables arranged in a ring.

Stochastic parametrisation of sub-gridscale processes can be used to explore model uncertainty. For each state of the resolved, macroscopic variables there are many possible states of the unresolved variables. It therefore seems unjustified to assume a one-to-one mapping of the large scale onto the small scale variables, as is the case in a deterministic parametrisation. A stochastic scheme is able to explore other nearby regions of the attractor compared to a deterministic scheme, and an ensemble generated by repeating a stochastic forecast gives an indication of the uncertainty inherent in the parametrisation process. A number of different stochastic parametrisation schemes were investigated, including the use of additive and multiplicative noise. Including a temporal autocorrelation to the noise term resulted in a significant improvement over white noise, challenging the standard idea that a parametrisation should only represent the sub-gridscale (both spatial and temporal) variability.

Skill scores were used to give a measure of the forecasting ability of different parametrisations, and their forecasting skill found to be linked to their ability to reproduce the climatology of the full model. This concept is of great importance in a seamless prediction system, allowing the reliability of short term weather forecasts to provide a quantitative constraint on the reliability of climate predictions from the same system.

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Equilibrium Distribution of Subgrid Convection: A Grand Canonic Ensemble Approach

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Moist convection on scales smaller than the horizontal grid spacing that is commonly used in operational numerical weather prediction (NWP) models is turbulent and therefore its interaction with the environment is, to a great degree, stochastic. Traditionally in operational NWP models, the effect of unresolved subgrid convection on the prediction of resolved scales is parameterized deterministically as an ensemble mean, and the stochastic fluctuations about this ensemble mean are ignored. It has recently been advocated that the stochastic fluctuations should be properly accounted for in the subgrid parameterization in order to address a persistent issue in operational ensemble prediction: the spread of ensemble members tends to be underestimated.

In this study, the probability of requiring n mutually independently convective plumes and a total cloud-base mass flux M for subgrid convection to occur in a given grid box is derived based on the concept of the grand canonical ensemble, which is well known in classic statistical mechanics. The probability distribution functions of the cloud-base mass flux and the number of subgrid convective plumes are dependent on the average of each of the two quantities. For a large number of such grid boxes in a given area, the concept can be extended to a homogenous stochastic situation. In this situation, the probability of finding exact k subgrid convective plumes in one of the grid boxes is given by the binomial distribution, which converges to the Poisson distribution when the number of the boxes approaches to infinity. The latter result provides an alternative way to derive and interpret the previous theoretical results obtained by Craig and Cohen (2006, JAS, Vol. 63, p. 1996-2015).

Treatment of the error due to unresolved scales in sequential data assimilation

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A novel method to account for model error due to unresolved scales in sequential data assimilation is proposed. An equation for the model error covariance required in the extended Kalman filter update is derived along with an approximation suitable for application with large scale dynamics typical in environmental modeling. The approach, referred to as Short Time Extended Kalman Filter (STEKF), is tested in the context of a low order chaotic dynamical system and it is compared with an EKF implementing a multiplicative covariance inflation, a practical procedure often used to account for model error in data assimilation. The results show that the performance of the STEKF is significantly better than that of the classical EKF with no additional computational cost and encourages the implementation of this approach in more realistic contexts.

Parameterization of atmospheric convection with conditional Markov chains

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The effect of clouds and convection on the state of the atmosphere is a major source of uncertainty in weather and climate models. Explicit modeling of convection requires model resolutions on the order of 50 meters, whereas global climate models have horizontal resolutions starting at ~100 km. As a consequence, the effects of convection in individual vertical model columns must be represented ('parameterized') in a simplified yet adequate way.

We use a new method to parameterize convection stochastically. A Markov chain is constructed by using realistic data obtained from large-eddy simulation (LES) of atmospheric convection. With a cluster method representative vertical heat and moisture flux profiles are found and the corresponding transition probability matrix is estimated by counting the number of transitions between profiles. By conditioning the probabilities on the atmospheric state, a conditional Markov chain (CMC) is obtained that can produce realistic turbulent fluxes. These fluxes are crucial for convection parameterization in weather and climate models.

Estimation and Value of Ambiguity in Ensemble Forecasts

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Ambiguity is uncertainty in the prediction of forecast uncertainty, or in forecast probability of a specific event, associated with random error in an ensemble forecast probability density function. In ensemble forecasting ambiguity arises from finite sampling and deficient simulation of the various sources of forecast uncertainty. Poor simulation of model-related uncertainty may be the largest contributor given the challenges involved.

This study introduces two practical methods to estimate ambiguity and demonstrates them on 5-day, 2-m temperature forecasts from the Japanese Meteorological Agency Ensemble Prediction System. The first method uses the error characteristics of the calibrated ensemble as well as the ensemble spread to predict likely errors in forecast probability. The second method applies bootstrap resampling on the ensemble members to produce multiple likely values of forecast probability. Both methods include forecast calibration since ambiguity results from random and not systematic errors, which must be removed to reveal the ambiguity. Additionally, use of a more robust calibration technique (improving beyond just correcting average errors) is shown to reduce ambiguity. Validation using a low-order dynamical system reveals that both estimation methods have deficiencies but exhibit some skill, making them candidates for application to decision making.

Two possible approaches for applying ambiguity information are explored. One application approach, called *uncertainty folding*, merges ambiguity with forecast uncertainty information for subsequent use in standard risk-analysis decision making. Uncertainty folding is found to be of no practical benefit when tested in a low-order, weather forecast simulation. A second approach, called *ulterior motives*, attempts to use ambiguity information to aid secondary decision factors not considered in the standard risk analysis, while simultaneously maintaining the primary value associated with the probabilistic forecasts. Following ulterior motives, the practical utility of ambiguity information is demonstrated on real-world ensemble forecasts used to support decisions concerning preparation for freezing temperatures paired with a secondary desire for reduction in repeat false alarms. Sample products for communicating ambiguity to the user are also presented.

Perturbations of surface parameters or how to stumble upon chaos... again

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MSC is running operationally a 20 member global Ensemble Prediction system (GEPS, 0.9x0.9L28, see Charron et al. 2010 and Houtekamer et al. 2010) up to Day 16. Also, dynamical downscaling is done using a 20 member regional REPS (Li et al. 2008, 33kmL28) over North America in experimental mode. The land surface model error is simulated with the use of 2 different surface schemes: Force-Restore (Mailhot et al., 1987) and ISBA (Noah and Planton, 1989) in the GEPS. In the REPS, only the ISBA scheme is used. Currently, the predicted atmospheric near surface fields like 2m temperature are under-dispersive. To increase ensemble dispersion, stochastic perturbations of the surface properties are added. Several parameters like leaf area index (LAI), plant fraction, albedo, soil moisture, soil temperature, sea surface temperature, land roughness and sea ice properties were perturbed using stochastic coefficients. The soil temperature and moisture which are variables that evolve along the runs are also perturbed. 2D Markov chains calculated following the Li et al. 2008 method are used to build perturbations. To better isolate the impacts, physical tendencies perturbations are not added and all members of the REPS are driven by the same initial atmospheric conditions and large-scale forcing.

In this poster, we present the results of a preliminary study using the REPS in summer 2009 (48 h forecasts). It was found that “chaos” via convection has introduced a systematic response in spread that might hide the impact of the surface perturbations. Therefore to identify the effect of perturbing individual surface parameter, the systematic “chaotic” response was subtracted from every individual test response.

It was found that the parameters with the largest impact on 2m temperature are Albedo, SST, LAI and vegetation fraction. While the variable with the biggest effect came out to be soil moisture. Sensitivity studies indicate that the impact increased more or less linearly with the amplitude of the surface perturbations. The overall effect of surface perturbations is modest when compared to the response to physical tendencies perturbations and to the large scale forcing (different initial and lateral conditions). However, integrating over different areas and over longer range, and coupled with assimilation may lead to different conclusions.

Representing convection in climate models with unified schemes

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There are well-known uncertainties and biases associated with the representation of convection in climate models. For instance, climate model simulations are characterized by a too early onset and peak of precipitation, over land and over ocean, as well as over the Tropics and the mid-latitudes. In this study we develop and explore the performance of a unified convection scheme capable of handling shallow and deep convection. Our approach is motivated by the results of cloud-resolving modeling studies which have documented the gradual transition occurring from shallow to deep convection and its possible importance for the simulated diurnal cycle.

Results from single column model experiments demonstrate the potential of the approach. The unified scheme realistically simulates cases of tropical oceanic convection, mid-latitude continental convection, and shallow maritime convection. In particular, the scheme succeeds in capturing the timing of the convective diurnal cycle. However, in full global climate model simulations, the performance is similar to the one of traditional schemes with a too early precipitation peak. The largest source of sensitivity and uncertainty in the scheme, as with traditional approaches, remains the formulation of appropriate entrainment and detrainment.

Laborious Linkage between Moist Physics Parameterization and Observations: Spin-down Problem in an NWP System

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Model error, contributing forecast error together with initial error and chaotic uncertainty in the atmosphere, stems from various sources such as parameterization types and statistical sub-grid fluctuations. The model error basically enlarges from the initial state and leads to a systematic bias in the model climatology, involving complicated horizontal and vertical interactions. In working on the hydrological cycle through further improvement of moist physics parameterization, therefore, diagnosing short-range forecast errors has been beneficially utilized to clarify the error source before interacting globally with unknown inherent predictability for not only numerical weather prediction (NWP) and thereby data assimilation (DA) and reanalysis but also climate prediction.

Considering the linkage between JMA's global NWP model and observations, there is a known, so-called "spin-down", problem associated with DA cycles, which is rapid adjustment to lower moisture values caused by a decrease in humidity accompanied by strong precipitation in the short-range period. Because the problem seems to be closely related to the convective precipitation, tackling the problem in light of a DA system is an important approach for evaluating moist physics parameterization (especially, convection scheme) in the model.

On the other hand, regardless of whether there is rain or not, retrieved global positioning system (GPS) total column precipitable water vapor (TPW) data can provide comparably accurate performance to retrieved Sonde TPW data. Moreover, because the ground-based GPS sites are distributed all over the world providing continuous data, the retrieved GPS TPW data gives informative estimation of hydrological cycles.

In this study, the operational convection scheme with spectral cloud ensemble is modified for both updraft and downdraft aiming to reduce the spin-down problem, considering not to produce too strong precipitation in the short range period and thereby to hold TPW in a column. Moistening and drying effects of current and modified convection schemes are assessed with ensemble variational analysis data (derived for the ARM TWP-ICE field campaign to account for the uncertainties in the radar derived rainfall estimates) and the hourly ground-based GPS TPW retrievals, using JMA's single column model (SCM) and global 4D-VAR DA system.

Preliminary results using the modified scheme demonstrate better TPW and precipitation time series in the SCM experiments and in the 4D-VAR DA system comparing with the ground-based GPS TPW data, though there is still room for improvement. Other results will be shown and discussed.

Atmospheric blocking in numerical weather and climate prediction models

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Atmospheric blocking is an important weather regime in mid-latitude weather and climate, as persistent blocking can induce extremely high or low temperatures and severe precipitation anomalies over the surrounding area. It has been well known that general circulation models tend to underestimate blocking frequency in numerical weather prediction (NWP) and climate projection. The accurate predictions and simulations of atmospheric blocking have remained an open question in NWP and climate projection, as is the case for the Madden-Julian Oscillation, tropical and extra-tropical cyclones.

In this study, model performances of state-of-the-art medium-range NWP and high-resolution climate models are assessed in terms of atmospheric blocking. Medium-range ensemble forecasts, available at the THORPXT Interactive Grand Global Ensemble (TIGGE) data portal, perform well in simulating the blocking frequency, even in the 9-day forecast, although the frequency is still underestimated in the 10-15 day forecast. In climate predictions of MRI-AGCM3.1 (TL959L60, TL319L60, and TL95L60) for the periods 1979-2003 and 2075-2099, the results reveal that the higher horizontal resolution is required to accurately simulate Euro-Atlantic blocking, whereas the higher horizontal resolution is not required to accurately simulate Pacific blocking. The blocking frequency is likely to decrease in the future climate, mainly in the western part of each peak in present-day blocking frequency. Wintertime long-lived blocking will disappear in the future, while summertime long-lived blocking will be still observed in the future.

Inclusion of Model Uncertainty in the U. S. Navy's Global Ensemble System

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Several different methods to incorporate model uncertainty and error in ensemble design have undergone testing in the Navy's global ensemble system using the Navy Operational Global Atmospheric Prediction System (NOGAPS). These include stochastic convection, stochastic kinetic energy backscatter, parameter variations, and a simple model of diurnal SST variations. As the initial perturbation method used is a cycling scheme (the ensemble transform), changes to model formulation have both a direct impact on the long forecasts, and an indirect impact on the initial perturbations (which are constructed from short-term ensemble forecasts). This indirect impact can be significant for short forecast lead times, especially in the tropics. It is found that the inclusion of model uncertainty has a significant impact in the tropics when considering several metrics (ensemble spread, ensemble mean RMS error, Brier scores, and tropical cyclone tracks). Specifically, while inclusion of model uncertainty does not have a substantial impact on ensemble mean RMS error, it does improve the Brier scores, and in some instances improves ensemble mean tropical cyclone track forecasts. For the parameter variations, decomposition of the Brier score indicates that improvement is obtained primarily through improved resolution, rather than reliability. Inclusion of a simple model of the SST diurnal cycle is shown to have an impact on the forecasts of the Madden Julian Oscillation.

Parameter estimation of a convective scheme using ensemble transform Kalman filter

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In this work the model state and parameters associated with a convective scheme are simultaneously estimated using ensemble transform Kalman filter (ETKF) in a simple general circulation model (SPEEDY).

The impact of parameter estimation upon initial conditions and short range forecasts are estimated using twin experiments which permits the evaluation of the technique under the assumption of the perfect knowledge of the true system evolution and the true parameters.

The method is successful in the estimation of the known parameters and introduces a significant improvement in the initial conditions and in the short to medium range forecast. The method is also able to estimate the evolution of time dependant parameters.

A new approach for the online determination of an optimal value for the parameter ensemble spread is provided. This approach consists in the inflation of the parameter ensemble variance in the ensemble space. Results show that the method is able to find an optimal relationship between the spread of the parameters and the spread of the state variables.

Two methods are evaluated for the inclusion of parameter estimation within a data assimilation cycle. The first one uses an ensemble with perturbations in the initial conditions and in the parameters and the second one uses two independent ensembles, one based on the perturbations of the initial conditions and other based on the perturbations of the parameters. Both methods are successful in estimating the known system parameters, however the first one is computationally more efficient.

Development and evaluation of stochastic physics schemes in the Unified Model - Preliminary results

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Despite the overall improvement of global numerical weather and climate prediction models over the last 20 years, prediction their uncertainty remains, because of limitations in the accuracy and representativity of the observations and model's incomplete representation of atmospheric processes and their interactions.

Some of the internal model uncertainty comes from the deterministic approach of the model formulation. Generally models are underdispersive and thus unable to accurately resolve process emerging from complex interaction across a wide range of scales like the Madden-Julian Oscillation (MJO) or the Quasi-Biennial Oscillation (QBO).

One possible solution for these problems is the use of stochastic physics, where the variability of sub-grid scale or highly diffused processes is backscattered into the model under certain probabilistic assumptions.

An evaluation of the impact of the model climatology, variability and predictability of two different stochastic schemes under development have been carried out inside the Met Office Unified Model framework, alongside other stochastic schemes already developed as Stochastic Kinetic Energy Backscatter (SKEB2) or Random Parameters (RP). The schemes evaluated are:

- Stochastic Perturbations of Tendencies (SPT), which provides a source of variability for the model deterministic parametrizations.
- Stochastic Vorticity Confinement (SVC), which forces stochastically vorticity structures whose features might have been lost by the inherent dissipation of the model. Although the Stochastic version is not fully developed yet, it has been proven to be a very good parametrization to counteract the high diffusivity of low resolution climate runs.

The seamless nature of the Met Office Unified Model, which uses the same physics for a wide range of timescales and resolutions allow us to test these schemes under a variety of spatial and temporal scales: 3 day Ensemble forecast using MOGREPS, seasonal using Glosea4 or climate scales using HadGEM3.

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Predicting Outliers in Ensemble Forecasts

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An ensemble forecast is a collection of runs of a numerical dynamical model, initialized with perturbed initial conditions. In modern weather prediction for example, ensembles are used to retrieve probabilistic information about future weather conditions. In this contribution, we are concerned with ensemble forecasts of a scalar quantity (say, the temperature at a specific location). We consider the event that the verification is smaller than the smallest, or larger than the largest ensemble member. We call these events outliers. If a K-member ensemble accurately reflected the variability of the verification, outliers should occur with a base rate of 2/(K+1). In operational forecast ensembles though, this frequency is often found to be higher. We study the predictability of outliers and find that, exploiting information available from the ensemble, forecast probabilities for outlier events can be calculated which are more skillful than the unconditional base rate. We show this analytically for statistically consistent ensembles and empirically for an operational ensemble using model output statistics.

Development of parameterizations for simulating moist convective boundary layers: an EDMF stochastic approach

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New unified EDMF parameterizations for boundary layer turbulence and convection, based on optimal combinations of classical Eddy-Diffusivity (ED) and Mass-Flux (MF) approaches, have successfully been able to reproduce some of the essential features of subgrid boundary layer mixing. However, faithfully reproducing the characteristics of moist convection is an extremely hard task using bulk plume models (or variants of these) alone. In this study we suggest that the solution to this problem is to introduce a stochastic parameterization of shallow moist convection plumes and of lateral entrainment. These stochastic plumes are drawn from a PDF produced by the EDMF parameterization without any additional ad-hoc assumptions. The essential implication of this study is that even in deterministic models, moist convection can only be simulated in a realistic manner using stochastic methodologies.

New schemes to perturb near-surface variables in MOGREPS

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MOGREPS consists of a 24-member ensemble, with a 60km resolution global model and an 18km regional model covering Europe and the North Atlantic region. Initial condition perturbations for the global system are derived from a 12-hourly cycling ETKF scheme. Stochastic physics include a KE backscatter scheme (SKEB) and random parameter scheme. Initial conditions for the regional system are interpolated 6-hour forecast differences between the perturbed member and corresponding control member in the driving global system.

Whilst there is reasonable agreement between the RMSE of the ensemble mean (EM) and the ensemble spread for many synoptic-scale variables in MOGREPS, the system is strongly under-dispersive for near-surface variables like 2m temperature and 10m wind. This poster describes new schemes in MOGREPS to perturb sea surface temperatures (SSTs) and soil moisture content (SMC) in an effort to increase ensemble spread of surface temperature and wind.

SST perturbations are generated using a random pattern with a spatial power spectrum derived from day-to-day changes in the Met Office Operational Sea Surface Temperature and Sea Ice Analysis (OSTIA) system. SMC perturbations are centred on the ensemble mean and passed from one forecast cycle to the next. Both schemes increase the ensemble spread of 2m temperature and 10m wind, particularly in the tropics. The impact of the SST perturbations is larger, possibly because of the longer persistence of SSTs.

A seamless approach to assessing uncertainties of climate models in predictions of severe extratropical windstorms

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Severe extra-tropical windstorms are amongst the most frequent and devastating natural hazards affecting Europe. Changes in the North Atlantic storm track position and storm intensity can have significant socio-economical impacts. However, predictions for the 21st century based on climate models are uncertain due to large disagreement between different models, between different ensemble members of the same model, and between climate models and observed climatologies of intense cyclones.

In this study current state-of-the-art climate models will be used for short-term simulations of 20 historic cases of the most severe/intense European winter windstorms. This seamless prediction approach, which draws from and expands on the experiments from the Transpose-AMIP initiative, will allow to separate and analyse sources of model errors resulting from fast processes (e.g. latent heating, surface fluxes) from those related to the models' basic states. In the long run, the climate model output will be assessed against high-resolution forecasts made with NWP models and analysis data with respect to storm intensity and track position. Main aspects of interest are the overall quality of the climate model forecasts and the identification of systematic biases, which could potentially be used to ‘calibrate’ climate model output for longer simulations.

Correction of model errors based on Model Output Statistics

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The dynamical properties of forecasts corrected using two different Model Output Statistics (MOS) schemes are discussed, with emphasis on the respective roles of model and initial condition uncertainties. The first scheme is based on the classical linear regression (referred as LMOS) and the second one takes into account the presence of errors in the predictors (referred as EVMOS).

MOS schemes are able to partly correct the effect of *both* initial condition and model errors. But the correction of uncorrelated random initial condition errors is small. For model errors, the corrections depend for short times on the mean of the velocity difference between the model and the reference system and on its covariance with the model observable(s). When more than one observable are used, the correction is highly sensitive to the specific choice of the additional observables.

For LMOS, the variance of the corrected forecast shows a progressive decrease as a function of lead time (convergence of MOS prediction toward the mean), precluding its use for ensemble forecasts. A modification of the classical scheme allows for keeping a correct (observed) variability of the MOS forecasts even at long lead times and is suitable for ensemble forecast correction. This new scheme (EVMOS) provides a unified framework for the correction of both deterministic and ensemble forecasts and one of the main advantages is to be able to post-process ensemble forecasts based only on information provided by past single deterministic forecasts. The ability of this new scheme in postprocessing ensemble forecasts has been explored successfully in the context of a low-order atmospheric model and of operational ensemble forecasts.

Representation of model uncertainty in ocean data assimilation for seasonal prediction in the POAMA system

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An ensemble ocean data assimilation system for the dynamical seasonal prediction model - the Predictive Ocean Atmosphere Model for Australia (POAMA; http://poama.bom.gov.au/) called PEODAS (POAMA Ensemble Ocean Data Assimilation System; Yin et al., 2011) has been developed and transitioned into operations. PEODAS is an approximate form of ensemble Kalman filter. It is based on a multivariate ensemble optimum interpolation (EnOI) system of Oke et al (2005), but uses covariances from a time evolving model ensemble. Both in situ temperature and salinity observations are assimilated, and current corrections are generated based on the ensemble cross-covariances with temperature and salinity.

The construction of the ensemble in PEODAS explicitly represents errors in surface forcing using an extension of the approach developed by Alves and Robert (2005), and the ocean model uncertainty is accounted for by introducing scaled random samples from a set of intraseasonal difference fields computed from a long model run without data assimilation. The random fields are sampled daily and added to each ensemble member gradually during the course of model integration using the incremental analysis updating procedure. Adding intraseasonal differences in this way is expected to help emphasizing error growth that is flow dependent and consistent with the growth of errors from the perturbed forcing. The additive error also plays a role as covariance inflation, which has a substantial effect on the accuracy of the ensemble data assimilation, especially in the regions where ocean model errors are significant. The relative importance and contribution of the error from different components of the PEODAS system are investigated by conducting several assimilation experiments that include errors from each component alone: e.g. from the forcing field only, from the model only, and an EnOI approach using static error covariances.

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Impact of Observation-Optimized Model Parameters on Decadal Predictions

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A skillful decadal prediction that foretells varying regional climate conditions over seasonal-interannual to multidecadal time scales is of societal significance. However, predictions initialized from the climate observing system tend to drift away from observed states towards the imperfect model climate due to model biases arising from imperfect model equations, numeric schemes and physical parameterizations, as well as the errors in the values of model parameters. Here I show how to mitigate the model bias through optimizing model parameters using observations so as to constrain the model drift in climate predictions with a simple decadal prediction model. Results show that the coupled state-parameter optimization with observations greatly enhances the predictability of the coupled model. While valid 'atmospheric' forecasts are extended by more than 5 times, the decadal predictability of the 'deep ocean' is almost doubled. The coherence of optimized model parameters and states is critical to improve the long time scale predictions.