Summer Monsoon precipitation over India – a comparison of model predicted and observed values.

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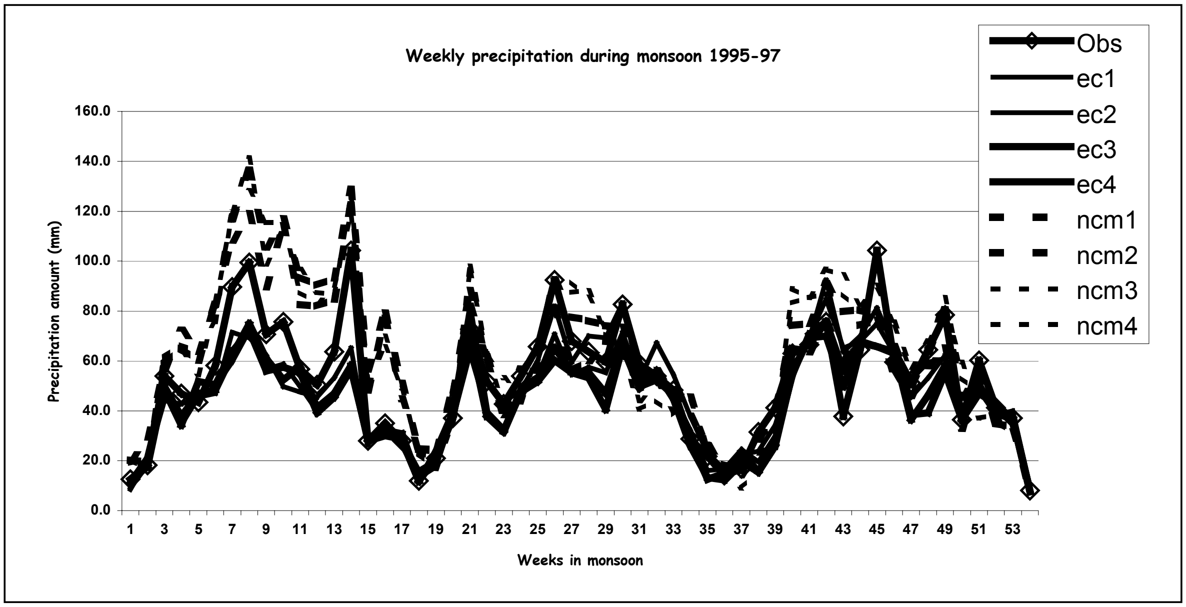
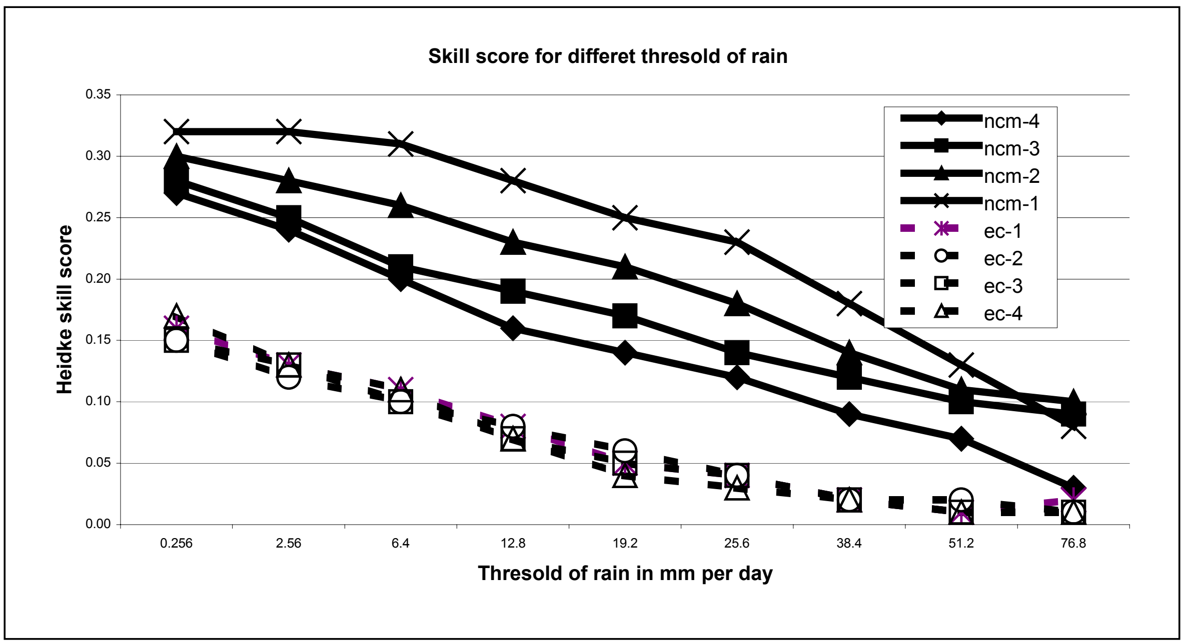
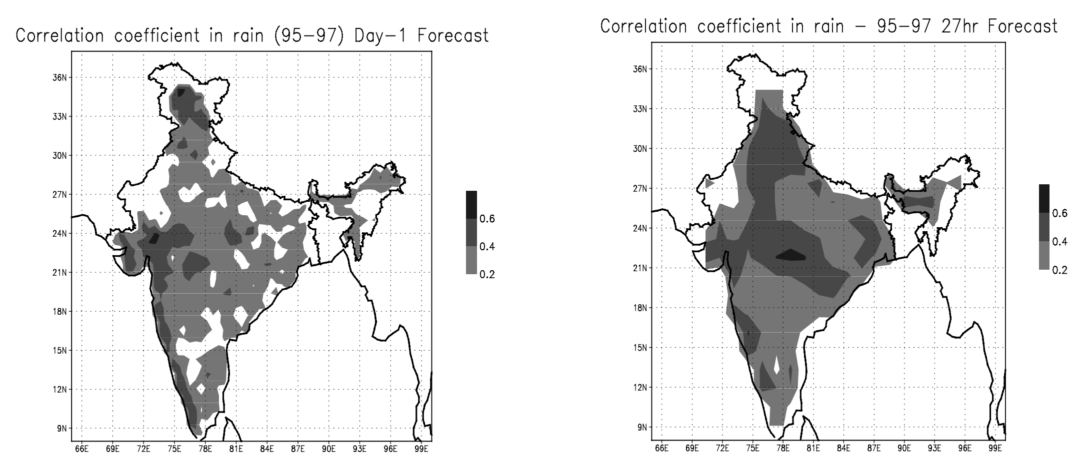
The precipitation forecasts over India from the ECMWF (T213) and the NCMRWF (T80) models for the monsoon seasons (1^{st} June to 30^{th} September) of 1995, 1996 and 1997 were compared with the observed rain gauge values. For quantitative comparison the observed values were averaged over the grid box areas representative of each grid point of the respective models. The spatial averaging is done by the Thiessen polygon method that assigns each elementary area to the rain gauge nearest to it and the weight of each rain gauge is the fractional area assigned to it.

The NCMRWF model forecasts have 10 to 15% more rainy days, mostly in the light or moderate precipitation categories, compared to the spatial average of observed values. Seasonal accumulated values of all India average precipitation show a slight spin up with forecast length for the NCMRWF model and a small spin down for the ECMWF model. The weekly-accumulated values of forecast precipitation from both models, averaged over the whole of India, are in phase with forecasts of length up to day-4.

Values of statistical parameters based on the frequency of occurrences in various classes indicate that the NCMRWF model has some skill in predicting precipitation over India during the summer monsoon. In spite of its low resolution, the NCMRWF model forecasts have higher trend correlation with the observed precipitation than the ECMWF model forecasts. This is due to the maximisation of data utilisation in the neighbourhood of India in the NCMRWF model. The mean errors across west coast is much reduced in the ECMWF model forecasts due to better representation of the mountain ridge line along coast. This indicates that a large part of the systematic error in the NCMRWF model is due to poor representation of the coastal topography and this will be removed with implementation of higher resolution. Both models have a tendency of over predicting the occurrences of light to moderate precipitation events and under predicting the events in heavier categories.







Correlation coefficient for day-1 forecasts of ECMWF model (left) and NCMRWF model (right).

The use of a hybrid vertical coordinate in the CMC-MRB Global Environmental Multiscale (GEM) model

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1. Introduction

Terrain-following coordinate framework has been introduced in atmospheric models in the late fifties and has been commonly used until recent research revealed the detrimental impact of such coordinate in computing the horizontal pressure-gradient term especially over steep orography. More recently it has been shown that the problem is highly amplified when using mesoscale NWP models (Schär et al., 02). Following, a hybrid vertical coordinate, which is terrain-following at low levels but tends continuously to pressure surfaces at upper levels, has been introduced in the Global Environmental Multiscale (GEM) Model developed by the Meteorological Research Branch (MRB) in partnership with the Canadian Meteorological Center (CMC) of Environment Canada (Côté et al., 98). Several studies have shown that the use of constant pressure surfaces in the stratosphere is more efficient for middle atmosphere studies and modeling than sigma surfaces, and very convenient for data assimilation (Laprise et al., 90). According to many Numerical Weather Predictions (NWP) operational centers, as the European Center for Medium-Range Weather Forecasts (ECMWF), this significant change is an important numerical improvement in the ongoing development of an integrated forecasts and data assimilation system.

2. The hybrid coordinate system and the extension of GEM in the stratosphere

The hybrid coordinate introduced in the GEM model is based on the Laprise and Girard (90) formulation, where the pression depends on a reference pressure set to 800 hPa and a coefficient *r* which controls the continuous transition from sigma surfaces at low levels to pressure surfaces at upper levels. The slope of the hybrid surfaces decreases rapidly with height hence limiting the truncation errors in the pressure gradient over steep terrain in the stratosphere. In order to assimilate new type of stratospheric data above 60 km, the GEM model was extended to the stratosphere with 80 hybrid levels up to 0.1 hPa.

3. Climate simulations of GEM

The new (hybrid coordinate) and old (eta coordinate) codes have been compared using NCEP analyses to produce a DJF climate of the stratospheric version of the model starting from 1978 to 1995. Zonal mean flow averages for January show that the models are zonally very similar with little differences in the stratospheric zonal wind in the tropics. Comparisons of the results against NCEP analyses point out some deficiencies of the GEM model to correctly simulate the physical phenomena in the tropospheric equatorial regions. Some effort are done at the RPN-MRB to improve the physical parametrizations of the model. In addition, the statistics show a strong tendency of the model to underestimate the zonal wind in the stratospheric winter hemisphere. This may be explained by the use of a gravity-wave drag scheme recently implemented in the operational model with a top level set to 10mb which significantly improves the analyses in this version of GEM but may not be adapted for stratospheric studies.

4. Behavior of the hybrid model in the upper stratosphere

In stratospheric regions where the wind increases with height the distortion over mountains of the sigma surfaces from the horizontal increases and leads to numerical errors in computing the pressure gradient term, hence generating spurious vertical waves in the upper layers of the stratosphere. Recent work of Trenberth and Stepaniak from NCAR (Trenberth et al., 02) shows such spurious structures in the horizontal divergent wind over the Andes in the NCEP reanalyses and suggested to switch to hybrid coordinate to avoid such problem. In the context of the hybrid

GEM model validation in the stratosphere, we compute the horizontal divergent wind for both versions (eta and hybrid) and found the same bahavior observed by Stepaniak and Trenberth with the eta version, that is spurious structures over steep orography, especially over the Andes, in the upper levels of the model from 1mb to 0.1 hPa which completely vanished using the hybrid version of GEM. Such spurious structures are also present in the zonal wind and temperature above steep terrains in the eta version but disappear in the hybrid version of the model, which clearly shows the benefit of the hybrid formulation in the stratosphere.

5. Conclusions

A hybrid vertical coordinate has been successfully introduced in the GEM model to replace the "terrain-following" eta coordinate used in the model since 1997. Using a stratospheric version with 80 levels up to 0.1 hPa, a DJF climate initiated by the NCEP analyses has shown some deficiencies of the model in the tropics and a tendency to underestimate the stratospheric jet in the winter hemisphere, which is under investigation at the RPN-MRB. Results above 1 hPa show significative improvement of the hybrid formulation over eta formulation due to reduced interpolation errors computing the pressure gradient term over steep orography. A stratospheric hybrid version of the 3D-Variational data assimilation of the CMC-MRB is now available and the next step will be to produce a complete analysis cycle in order to validate the model against analyses, and further to assimilate additional observations in the stratosphere (AMSU-A, AIRS,..).

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A REDUCED SPHERICAL TRANSFORM FOR THE NCEP SEASONAL FORECAST GLOBAL SPECTRAL ATMOSPHERIC MODEL

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A reduced sperical tranformation (RST) is applied to the NCEP atmospheric global spectral model for seasonal forecast. It is the same concept as the reduced Gaussian grid (Williamson and Rosinski, 2000). The magnitude of the associated Legendre coefficient has a scalene right triangle pattern, which provides the basis of the RST.

The proposed RST computes fewer latitudinal waves and Lengendre tranformations than the right-angle trapezoid pattern used by all reduced-Gaussian-grid global spectral models (see Fig. 1). In order to ensure reproducibility by model restart and to avoid modification of the model preprocessor and postprocessor, we use a nearest-point-replacement method for preparation of the surface data between a full Gaussian grid for fully spherical transform (FST) and reduced Gaussian grids for RST after initial interpolation.

The advantages of scalene right triangular transformations are that they save an extra 50% of computational resources over the trapezoid Legendre transformations, and scalene transformations are easier to load balance for massive-parallel-processor computing.

A comparison without model physics, between scalene RST, trapezoid RST, and FST indicates that they have negligible differences up to 15 days and acceptable differences up to one month. And when the comparison includes model physics, the results show negligible differences up to 7 days, but the chaotic nature of the system, known as internal variability, produces significant differences among RSTs and FST in monthly integrations. Nevertheless, the seasonally averaged results from 10 years of AMIP-type runs show that the runs using RST and FST are similar. The results indicate that they have the same model climatology (see Fig. 2). From these experiments, this scalene RST (as compared with the FST) can be used for short-range as well as seasonal or climate prediction.

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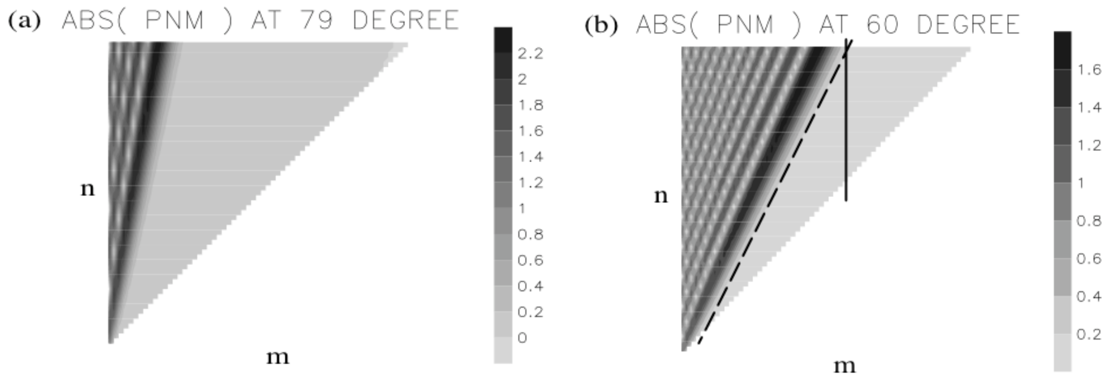

Fig. 1. The absolute amplitude of the associated Legendre function for T62 at latitudes of (a) 79 and (b) 60 N. The solid line (Fig 1(b)) indicates the trapezoidal truncation and the dashed line indicates the scalene triangular truncation.

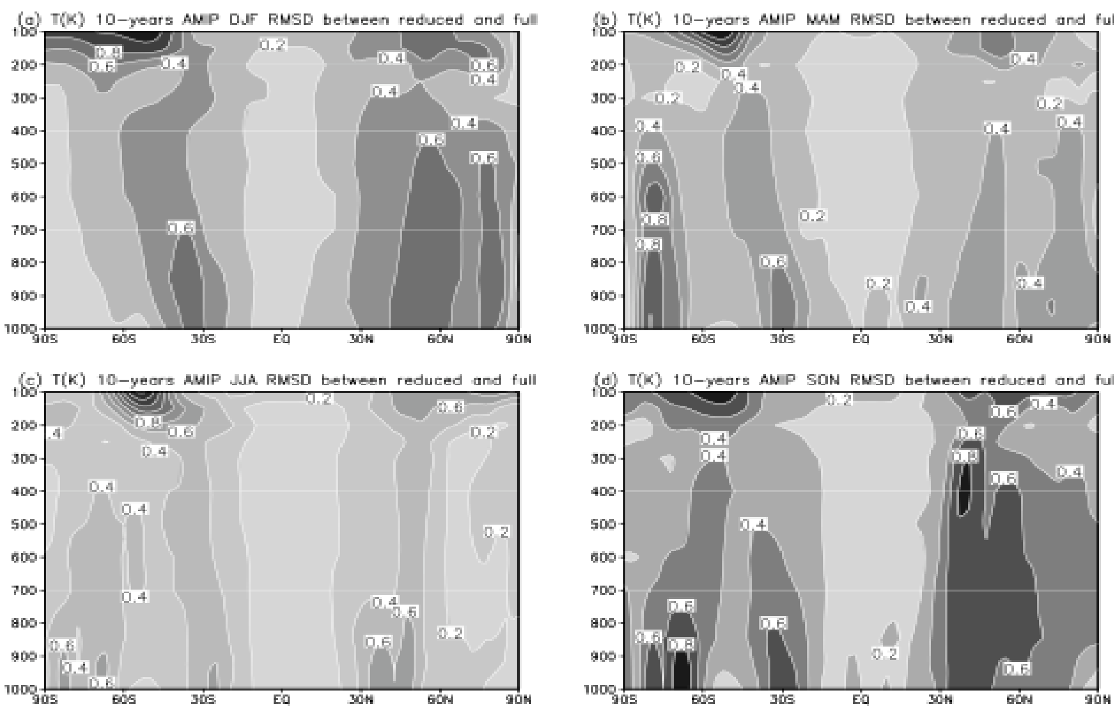

Fig 2. Root Mean Square Difference (RMSD) of 10-year zonal seasonal-mean temperature between reduced and full spherical transforms, plotted for (a) winter, (b) spring, (c) summer, and (d) fall, with contour interval of 0.2 K.

Optimal-controlled Ensemble Prediction Technique and its Application in ENSO Prediction

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1. Introduction

More and more researchers are focusing on how to reduce the effects of initial errors on numerical prediction while others examined the effects of chaos in the atmosphere (Lorenz 1963) and diversity of numerical models. As a result, four-dimensional variational data assimilation (4D-VAR) and ensemble prediction (EP) techniques have been developed.

The method of 4D-VAR (Lewis and Derber 1985; Talgrand and Courtier 1987) was developed to use observations at different spatial and temporal points to optimize model initial conditions while assuming a perfect model.

The EP technique (Tracton and Kalnay 1993; Toth and Kalnay 1993) is based on the assumption that very small errors in the initial conditions can induce appreciable changes in the forecast. It also assumes that the numerical models are not perfect, each model having it own skill. The main problem in EP is how to generate the perturbations. Singular vector (Tracton and Kalnay 1993) and breeding of growing modes (Toth and Kalnay 1993) are some typical methods.

In this study, we combine 4D-VAR and EP techniques as an optimal-controlled ensemble prediction technique to predict ENSO events using an imperfect model and imprecise observations.

2. The technique

If the prediction model is

$$X_t = M(X_{t-1}) \quad (1)$$

where M is the numerical model, X_t and $X_{t\text{-}1}$ are atmosphere states at time t and t-1 respectively, and the reality at time t is Y_t, the forecast error is

$$\varepsilon_t = X_t - Y_t \quad (2)$$

The error includes two parts: one is due to the error of the model itself, another is induced by initial condition errors. In other words, the numerical model can only describe part of the atmospheric variation that can be written as the inner product of the model forecast variation δX_t and forecast error ε_t as $<\varepsilon_t, \delta X_t>$. The aim of weather forecast is to minimize the mode

$$\left\|\left\langle \varepsilon_t, \delta X \right\rangle\right\|$$

According to theory of 4D-VAR,

$$<\varepsilon_t, \delta X_t> = <\varepsilon_t, L\delta X_0> = <L^*\varepsilon_t, \delta X_0>,$$

where L and L^* are continuous linear operators of the model M and its adjoint respectively. In the adjoint model, this can be written as

$$\sigma = L^* \varepsilon_t$$

Meanwhile, to minimize mode $|| < \varepsilon_t, \delta X_t > ||$ is equivalent to minimize mode $|| \left\langle L^* \varepsilon_t, \delta X_0 \right\rangle ||$, which can be achieved by introducing a disturbance $W\sigma$ (where W is a weight coefficient) in the initial conditions. From the EP perspective, $W\sigma$ is the required disturbance. Here, the disturbance $W\sigma$ differs from the disturbance in the usual EP technique because it is an optimal value controlled by observations and the model itself using the 4D-VAR technique. On the other hand, (2) indicates that model forecast error is a function of the length of forecast time. Likewise, the disturbance $W\sigma$ is a function of forecast time. Therefore, the optimal-controlled EP technique can be described as using 4D-VAR technique with a different length of forecast time to calculate a set of disturbances and to get a set of EP members.

3. Model and results

The simple Cane-Zebiak air-sea coupled model (Cane et al. 1986) is used and its adjoint model is developed in this study. An optimal-controlled EP system is established based on the 4D-VAR system. Monthly-averaged sea-surface temperature anomaly (SSTA) from 1971 to 1998 from the National Centers of Environmental Prediction (NCEP) and wind field at 1000 hPa from the reanalysis data of NCEP are used. EP members are formed by setting assimilation period as 3, 6, 9, 12, 15, 18, 24, 27 and 30 months. There are 10 members including the control run (without disturbance in initial conditions) with 277 cases from June 1973 to June 1996. Each case has 18 months of NINO3 index forecast.

Figure. 1 gives the time variations of skill (correlation coefficient) of each member while Fig. 2 gives those of the control, EP and persistence forecast. In EP scheme 1, the average weight coefficient of each member is the same, while in EP scheme 2, the average weight coefficient of each member is calculated according to its skill as in Fig.1. Figure 3 is the mean square of NINO 3 index forecast error. The EP schemes have higher skill and lower errors (Figs. 2 and 3), especially in EP scheme 2. Therefore, the optimal-controlled EP technique can improve the forecasting skill evidently even using a simple numerical model.

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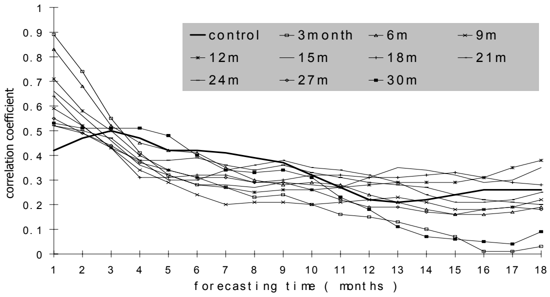

Fig. 1. NINO 3 forecast skill of each EP member (with different assimilation period).

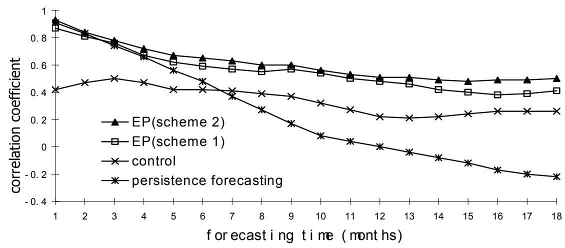

Fig. 2. NINO 3 index forecast skill of EP (schemes 1 and 2), control and persistence forecasting.

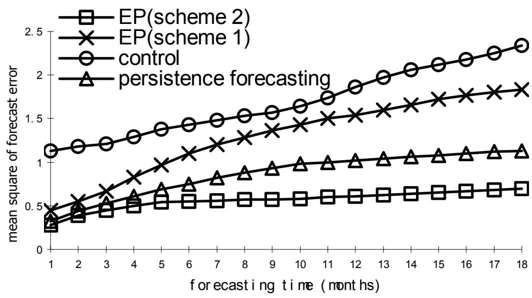

Fig. 3. Mean square of NINO3 index forecast error.

GLOBAL ATMOSPHERIC SIMULATIONS WITH THE T1279L96 RESOLUTION

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An atmospheric general circulation model (AGCM), which runs extremely efficiently on the Earth Simulator (ES)[1] was developed[2]. The ES is a gigantic vector parallel computer system. With the combination of our AGCM, AFES (***A**GCM **f**or the **ES***), and the ES, we have performed 10-km mesh (T1279L96) global atmospheric simulations, targeting typhoon genesis, Baiu-Meiyu frontal zone and wintertime cyclogenesis. A snapshot of global precipitation field from one of such simulations is shown in Fig. 1. It shows both large-scale features, such as the inter-tropical convergence zone and mid-latitude lows, and meso-scale features, such as the typhoons that are located over the western North Pacific and fronts which are associated with cyclonic activities. Although verification of model results is still underway, Fig. 1 suggests the feasibility of use of global ultra-high resolution simulations for studies on, for example, self-organization of meso-scale structures in the general circulation, and the interaction between meso-scale phenomena and larger-scale circulation.

AFES is a primitive equation spectral Eulerian AGCM. Physical processes include a simplified form of Arakawa-Schubert cumulus convection scheme with the effect of downdraft and rather sophisticated radiation scheme. AFES was adopted from an AGCM jointly developed by Center for Climate System Research, the University of Tokyo and Japanese National Institute for Environmental Studies[3]. However, AFES has been totally rewritten from scratch with FORTRAN90, Message Passing Interface (MPI) and microtasking. The original code was written in FORTRAN77 and not parallelized.

AFES achieved the computational speed of about 27 Tflops (about 65% of the peak performance) with the full configuration of the ES (about 41 Tflops, 640 nodes, 5120 CPUs)[2]. It was recognized as the fastest computation in the world at the Super Computing 2002, November, 2002, Baltimore, MD, USA, and won Gordon Bell Prize for peak performance. Fig. 2 shows AFES's speed as a function of the number of processors. It clearly shows AFES is very scalable up to 5120 processors or the full configuration of the ES.

Fig. 3 shows an example of meso-scale features simulated in the typhoon genesis experiment. A clear "eye" of one of the typhoons is well simulated. Although vigorous verification against observations is yet to be done, Fig. 3 is certainly very encouraging.

So far AFES is merely an ultra-high resolution version of a conventional AGCM. We have been working on "modernizing" AFES. We have been experimenting with some other cumulus parameterization schemes rather than the Arakawa-Schubert-type scheme. Also we have implemented conservative Semi-Lagrangian scheme in tracer transport[4].

The T1279 resolution is used for rather short-term (10~16 days) simulations due to computational resource. We plan to use T319~639 resolution for more climate-oriented studies, such as interannual variability or global warming, in the near future.

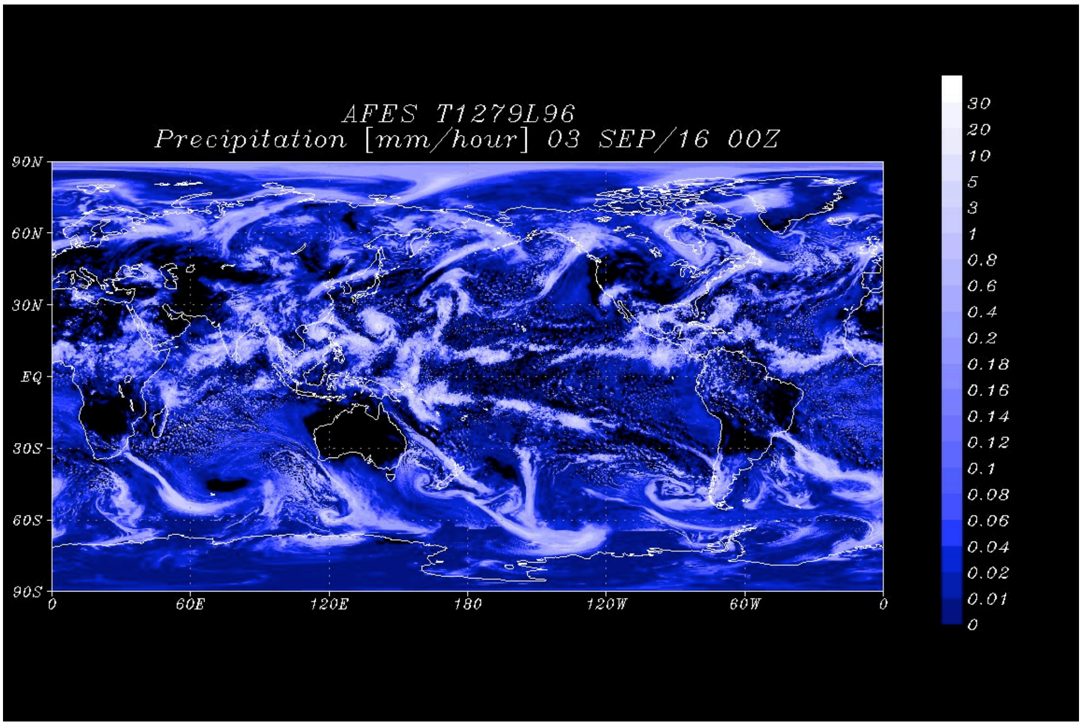
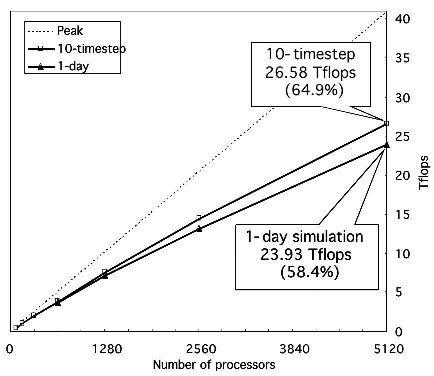


Fig. 1. Snapshot of global precipitation field from one of T1279L96 simulations.



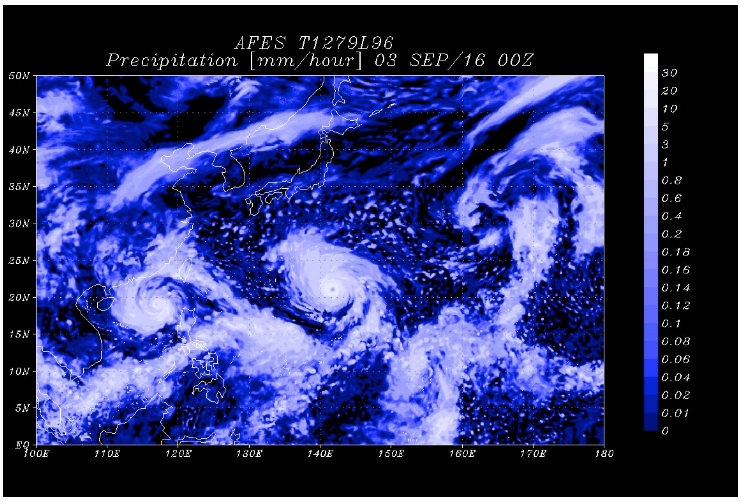


Fig. 2. Scalability of T1279L96 AFES.

Fig. 3. Magnified figure of Fig. 1. around the Japan area.

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Development of a European Multi-Model Ensemble System for Seasonal to Inter-Annual Prediction (DEMETER)

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1. Introduction

Seasonal forecasts are clearly of value to a wide cross section of society, for personal, commercial and humanitarian reasons. Dynamical seasonal forecasts have been made using ensemble systems with slightly different initial conditions. However, if uncertainties in initial conditions are the only perturbations represented in a seasonal-forecast ensemble, then the resulting measures of predictability will not be reliable; the reason being that the model equations are also uncertain. One approach to solve this problem relies on the fact that global climate models have been developed somewhat independently at different climate institutes. An ensemble comprising such quasi-independent models is referred to as a multi-model ensemble. The ability of multi-model ensembles to produce more skilful probability seasonal forecasts will be presented in this contribution.

The DEMETER project[1] (Development of a European Multi-model Ensemble System for Seasonal to Interannual Prediction) has been funded under the European Union Vth Framework Environment Programme to assess the skill and potential economic value of multi-model ensemble seasonal forecasts. The principal aim of DEMETER was to advance the concept of multi-model ensemble prediction by installing a number of state-of-the-art global coupled ocean-atmosphere models on a single supercomputer, and to produce a series of six-month multi-model ensemble hindcasts with common archiving and common diagnostic software.

2. Description of the experiment

The DEMETER system comprises 7 global coupled ocean-atmosphere models: CERFACS (European Centre for Research and Advanced Training in Scientific Computation, France), ECMWF (European Centre for Medium-range Weather Forecasts), INGV (Istituto Nazionale de Geofisica e Vulcanologia, Italy), LODYC (Laboratoire d'Océanographie Dynamique et de Climatologie, France), Météo-France (France), Met Office (UK) and MPI (Max-Planck Institut für Meteorologie, Germany). In order to assess seasonal dependence on forecast skill, the DEMETER hindcasts have been started from 1st February, 1st May, 1st August, and 1st November initial conditions. Each hindcast has been integrated for 6 months and comprises an ensemble of 9 members. In its simplest form, the multi-model ensemble is obtained by merging the ensemble hindcasts of the seven models, thus comprising 7x9 ensemble members. The performance of the DEMETER system has been evaluated from a comprehensive set of hindcasts over a substantial amount of years, with the main focus in 1987-1999 (Palmer et al., 2003).

To enable a fast and efficient post-processing and analysis of this complex data set, much attention was given to the definition of a common archiving strategy for all models. A large subset of atmosphere and ocean variables, both daily data and monthly means has been stored into the ECMWF's Meteorological Archival and Retrieval System (MARS). A significant part of the DEMETER data set (monthly averages of a large subset of surface and upper-air fields) is freely available for research purposes through an online data retrieval system installed at ECMWF[2].

A comprehensive verification system to evaluate all DEMETER single models as well as the multi-model DEMETER ensemble system has been set up at ECMWF. The system runs periodically to monitor hindcast production, to quality control the data (and correct archival) and to calculate a common set of diagnostics. The basic set of diagnostics (performed in cross-validation mode) comprises: global maps and zonal averages of the single-model bias, time series of specific climate indices, standard deterministic and probabilistic measures of forecast quality and a comparison of single-model ensembles skill with that of multi-model ensembles.

3. Results

Sea surface temperature skill assessment over the tropical Pacific suggests that both, the multi-model ensemble and the single models perform at levels comparable to dedicated ENSO prediction models and much better than persistence. In general, the identity of the most skilful single model varies with

[1] A complete description of the project and its main results can be found on the DEMETER website: http://www.ecmwf.int/research/demeter

[2] Monthly data can be retrieved in GRIB and NetCDF from http://www.ecmwf.int/research/demeter/data

region and year. Deterministic skill measures indicate that, in most years, the multi-model ensemble skill is close to the best single-model skill and is the most skilful when performance is averaged over all years. However, a key result was that multi-model ensemble probability scores were generally better than those from any of the single-model ensembles. The greater probabilistic skill of the multi-model ensemble compared to the single-model skill leads to an increased potential economic value (Richardson, 2000). For instance, it has been found that, for predictions of positive tropical winter (December to February, November start date) precipitation anomalies, the multi-model ensemble improves potential economic value from 15% to 80%, depending on the single model taken as reference (not shown).

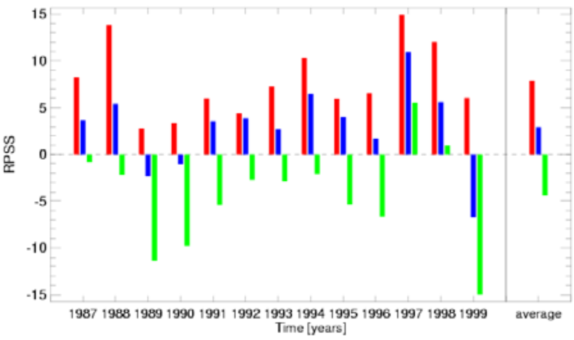

Figure 1: Ranked probability skill score for the 1-month lead tropical summer (JJA) precipitation 1987-1999 for the 54-member DEMETER multi-model ensemble (red), and the single ECMWF ensemble with 54 (blue) and 9 members (green). Average results are shown on the right end of the plot.

In spite of the clear improvement of the multi-model ensemble performance an important question arises. This improvement could be due either to the multi-model approach itself or to the increased ensemble size resulting from collecting all members of the single-model ensembles, or both. In order to separate the multi-model benefits that derive from combining models of different formulation to those derived simply from the accompanying increase in ensemble size, a 54-member ensemble hindcast has been generated with the ECMWF model alone for the period 1987-1999 using a single start date (May, boreal summer). As forecast quality measure, the ranked probability skill score for tropical summer (June to August) precipitation positive anomalies for a 54-member multi-model ensemble (red bars) and the ECMWF model (blue bars) is shown in Figure 1. Tercile categories have been used. The multi-model ensemble for this example was constructed by randomly selecting 54 members out of the 63 available in the multi-model hindcasts. Values for the ECMWF model 9-member ensemble are also shown (green bars). The single-model skill increases with ensemble size, though it turns out that the multi-model outperforms the single-model skill regardless of the ensemble size. Similar results are found for other variables and regions. It has been found that the largest contribution to the multi-model ensemble skill improvement is due to an increase in reliability.

4. Conclusions

As part of a European Union-funded DEMETER project, a multi-model ensemble system based on 7 European global coupled ocean-atmosphere models has been described and validated in hindcast mode using the ECMWF Re-Analysis ERA-40 data. Results indicate that the multi-model ensemble is a viable pragmatic approach to the problem of representing model uncertainty in seasonal-to-interannual prediction, and will lead to a more reliable forecasting system than that based on any one single model. As a result of the success of DEMETER, real-time multi-model ensemble forecasting is now being established as part of the operational seasonal forecast suite at ECMWF.

The DEMETER project has applications partners in agronomy and in tropical disease prediction. These models have been directly linked to the output of individual members of the multi-model ensemble, after correction of the bias and downscaling onto a finer grid than the one used in the coupled models. As such, the design of DEMETER was based on the concept of an “end-to-end” system, in which users can feed information back to the forecast producers. Results from the application models show that multi-model seasonal forecasts have useful economic value.

Acknowledgements

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Ensemble Configurations for Typhoon-related Rainfall Forecasts

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Typhoon-related precipitation forecasts are investigated in this study utilizing three ensemble configurations. The ensemble configurations are the multi-analysis (MA), the multi-convection (MC), and the multi-model (MM). Each configuration comprises a set of six members with a common component. The MA components are obtained from the assimilation of five different rainfall algorithms (FERRARO, OLSON, SSMI/TMI, TURK and TMI2A12) into initial analyses within the FSU physical initialization and prediction system. The MC configuration is devised by incorporating six cumulus parameterization schemes (FSU, NCEP/SAS, GSFC/RAS, NRL/RAS, NCAR/ZM, and EMANUEL) into the FSUGSM. The set of MM ensemble members is provided by five operational center forecasts (BMRC, JMA, NRL, RPN, and NCEP) in addition to an FSU control forecast.

In the deterministic ensemble forecast, three ensemble means are employed to intercompare the predictability of the above configurations. These are regular ensemble mean, individually bias-corrected ensemble mean (BCE), and superensemble (SE). In the SE method, the a priori weighting statistics is computed using the dynamic linear model method (Shin and Krishnamurti, 2003). Thirty-one cases are identified from Typhoons Damrey, Kirogi, Kai-Tak, Jelewat, and Ewiniar occurred in 2000. TRMM satellite rain rates are treated as our benchmark observation and used in forecast verifications.

The MA and the MM ensemble members produced the smallest and the largest spreads, respectively, in the typhoon track forecasts. The average variances of latitude were larger than those of longitude due to the direction of typhoons studied. The best ensemble mean track forecasts were made by the MM configuration.

Figure 1 visualizes the skill differences of the BCEs for the MA, MC, and MM configurations. The 5-day average skill scores of the MM with respect to the MA and MC are approximately 34% and 17%, respectively.

The skill of MM SE forecast almost always surpasses those of any combination of ensemble configurations and means. The MM SE rainfalls for days 1 to 5 are compared to the observed rainfall estimate in the left side of Fig. 2. These are 24-h accumulated precipitation forecasts at the end of days 1 to 5, all valid for August 16, 2000. The panel (a) presents the observed precipitation field based on satellite microwave instruments. The accuracy of forecast continues to slowly deteriorate as forecast lead time increases. The RMSEs and correlation coefficients are respectively 5.90/0.78, 7.11/0.66, 7.13/0.65, 7.64/0.57, and 8.82/0.35 for days 1 to 5 forecasts in this example. This figure exemplifies a key role of SE approach, compared to other ensemble means.

Panels (b), (c), and (d) in the right hand side of Fig. 2 illustrate day 3 MA, MC, and MM probability of precipitation (POP) forecast maps for 10 mm/d of precipitation threshold, respectively. The associated event occurred is shown in the panel (a). The probability higher than 0.5 is shaded in panels (b), (c), and (d). In comparison of probability maps for the MA, MC, and MM, we can notice that there is a good correspondence with each other. However, the BSSs are -8.71, 3.20, and 23.66 respectively. As the skill scores said, there is more disagreement between the POP and event occurred in the MA and MC than in the MM. Although the skill for the MA forecast is less than zero, there exists a recognizable agreement between the POP forecast and observation. It is unreasonable to say, therefore, that climatological forecasts based

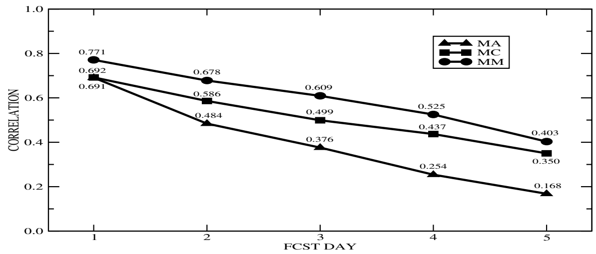

Figure 1:

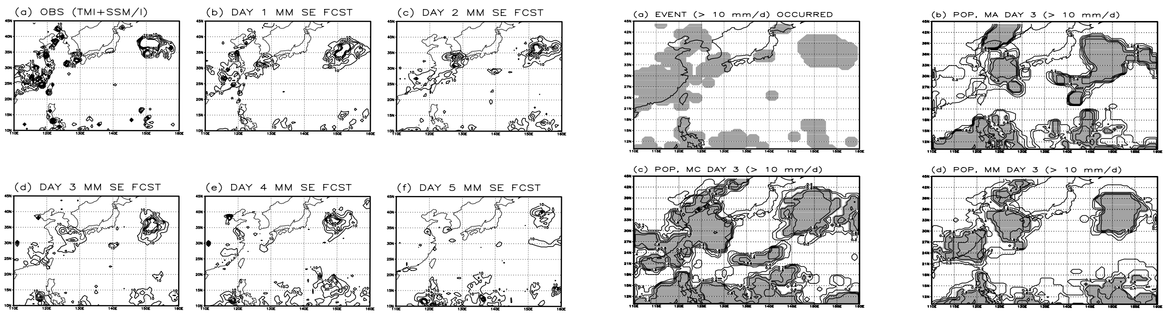

Figure 2:

on observational uncertainty are better than the MA ensemble forecast system. At the least, state-of-the-art NWP models predict rational signals for precipitation events. But, they have inherent deficiencies in making forecasts of the proper magnitude and location of those events. Overall, the above result clearly verifies that the medium-range POP forecast contains a fair amount of skill with a properly prepared ensemble system.

In summary, typhoon-related precipitation systems are best predicted by the MM configuration from both deterministic and probabilistic viewpoints. The single model ensemble setups (MA and MC) contain more biases than the MM setup. A weighed ensemble, the so-called superensemble (SE), technique shows a slight increase in forecast skills, compared to the bias-corrected ensemble.

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Changes of the zonal atmospheric circulation at the Last Glacial Maximum as it is simulated by atmospheric global circulation models in PMIP

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Complexity of the atmospheric circulation raises a problem of looking for simple clear indices combining circulation features into short and expressive picture. For evaluation of the global zonal winds regime in work [Petrossyants, Gushchina, 1998] new index of zonal wind speed component was successfully applied. It is calculated by integration of zonal wind speed along the latitude. The positive values of an index testify to prevalence of western circulation, negative – of eastern circulation.

Previous works demonstrated, that the index adequately reflects features of modern atmospheric circulation. That fact has allowed us to apply it to research climate modeling results simulated by atmospheric general circulation models (AGCMs) and to evaluate circulation changes at Last Glacial Maximum (LGM: ca 21,000 calendar yr B.P., equivalent to ca 18,000 ^{14}C yr B.P.) simulated by these models. Monthly mean values of simulated zonal wind speed for present-day (17 AGCMs) and LGM (8 AGCMs) climate scenarios were taken from PMIP (Paleoclimate Modelling Intercomparison Project) database. Analysis was carried out for simulations with fixed sea surface temperature. Global atmospheric circulation for current climate (control run) and 21 ka is studied at 850 and 200 hPa isobaric surfaces.

Before to use the index for palaeoscenario it was applied for simulated zonal wind component of present day climate (fig.1). Results had been compared with index values calculated on the base of NCEP/NCAR Reanalysis 1948-1997 [Sourkova, Gushchina, 2002]. Comparison showed satisfactory agreement and allowed to proceed to calculations for LGM.

Before to compare circulation for LGM and control run, we calculated mean index values within all incorporated AGCMs for the control run and LGM run, and then for each time snapshot we determined standard deviation from that mean values. Thus we could analyze intermodel variability. Use of t-criteria of Student distribution allowed us to conclude that differences of LGM and control run indicies are mostly at the significant level [Sourkova, 2003].

On the base of calculated index we may say that zonal circulation changes 21 kyr ago had a strongly expressed features, especially in the southern hemisphere and in tropics (fig. 2).

In a southern hemisphere there is a displacement of an axis of the maximum of zonal western circulation to the south, while values of index maximum in this zone grow during the year on 850 hPa and since november till march on 200 hPa. In a tropical zone the maximum of east circulation is moved northward only on 850 hPa, but the intensity of east circulation on an axis of maximal values is less then for present-day climate within all year. On the 200 hPa situation of an axis of the most intensive east circulation differs from the current climate, but the intensity of circulation is increased along the axis during the year. The changes of zonal wind speed circulation of in a zone of the westerlies in northern hemisphere have the same features, as zone of western winds of a southern hemisphere, but they are expressed much less.

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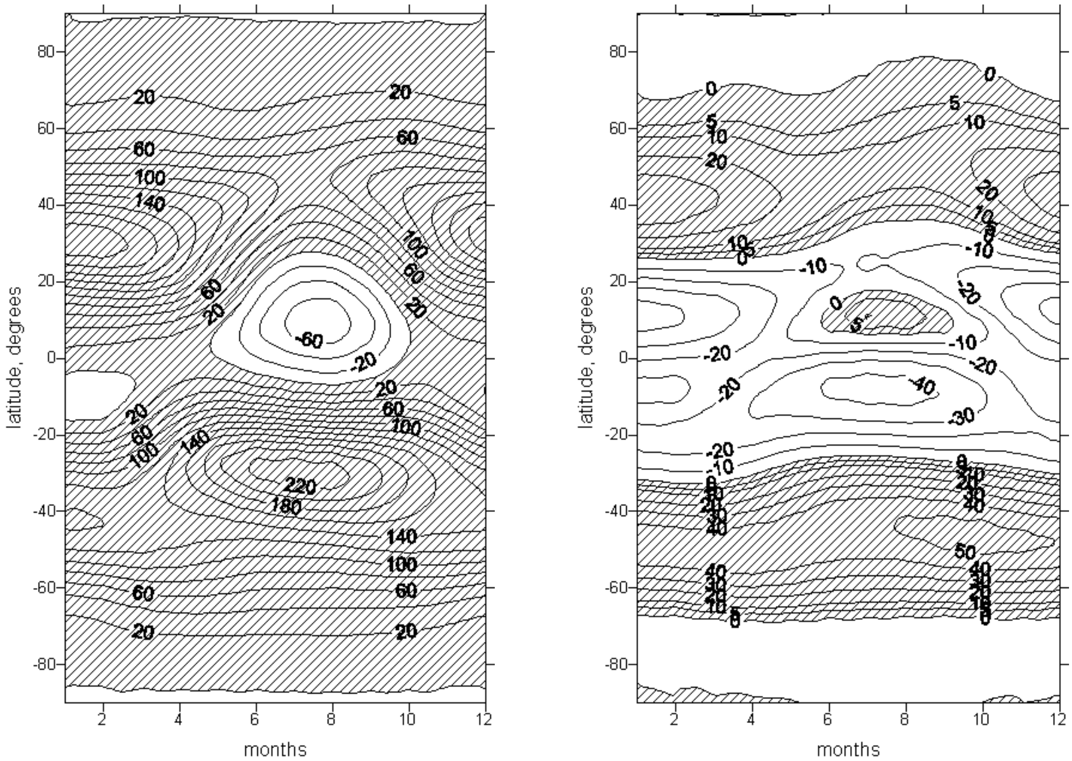

Fig.1. Annual changes of the zonal wind speed circulation index for the control run at 200 hPa (a) and 850 hPa (b)

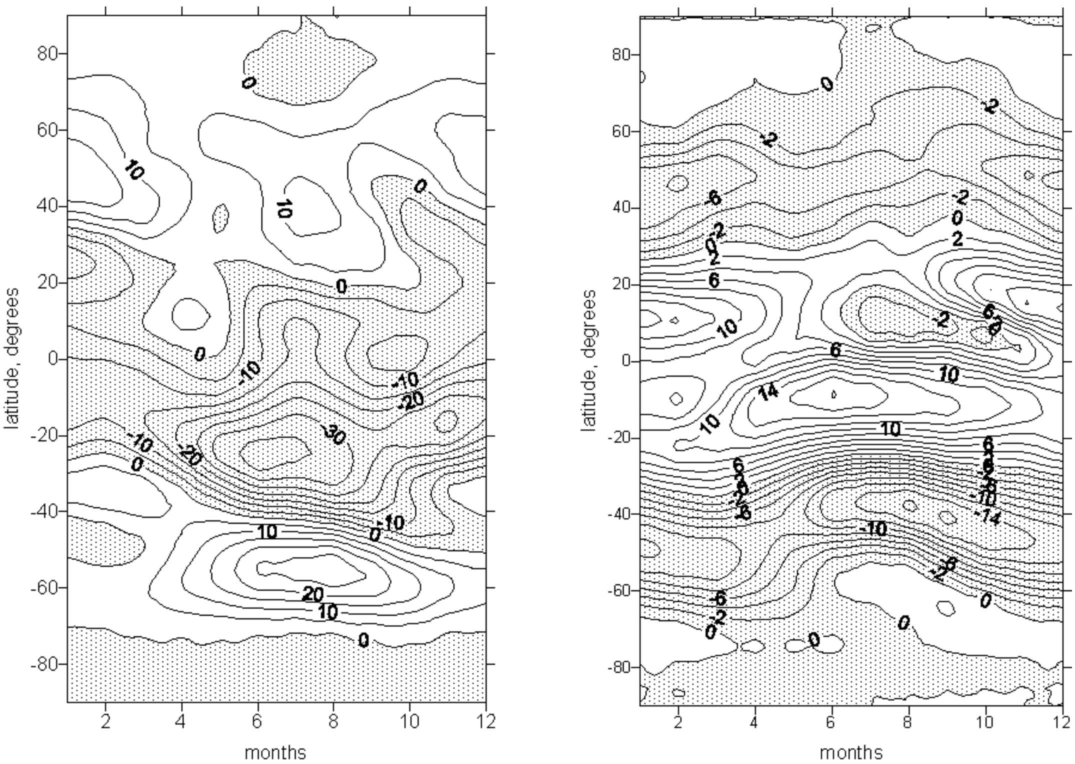

Fig. 2. Differences of the zonal wind speed circulation index between LGM and control run at 200 hPa (a) and 850 hPa (b)