WORLD METEOROLOGICAL ORGANIZATION

COMMISSION FOR BASIC SYSTEMS

OPAG ON
DATA PROCESSING AND FORECASTING SYSTEMS

REPORT OF WMO/KMA WORKSHOP OF GLOBAL PRODUCING CENTRES ON LEAD CENTRE FOR LONG-RANGE FORECAST MULTI-MODEL ENSEMBLE PREDICTION

Busan, Republic of Korea, 18-20 September 2007

Final REPORT

Executive summary

A Workshop of Global Producers of Long Range Forecasts (GPCs) was held, at the kind invitation and support of the Republic of Korea, in Busan from 18 to 20 September 2007. Twelve participants representing the nine GPCs and Moscow as future new GPC attended the workshop. The workshop participants decided to nominate Dr Richard Graham, chairman of the new CBS Expert Team on ELRF, to act as chairman for leading its work and general discussion. The nine GPCs and Moscow presented the status of their operational activities and current development. The main objectives of this workshop were considered:

- Review the status of development for Lead Centre for Long Range Forecast Multi-Model Ensemble prediction (LC-LRFMME)
- Refine needs for and functions of LC-LRFMME
- Propose recommendations related to LC-LRFMME tasks and GPCs role for LRFMME production and access/distribution of products.

The representative of GPC Seoul presented a report of the activities of the centre in the perspective of the implementation of a Lead Centre for LRFMME.

The tasks of the Lead centre were reviewed and there was a consensus to refine the list of functions of the Lead Centre for LRFMME as follows:

1. Maintain a repository of documentation for the system configuration of all GPC systems
2. Collect hindcast and forecast data from GPCs
3. Display GPCs forecasts in standard format
4. Promote research and experience in MME techniques and provide guidance and support on MME techniques to GPCs, RCCs and NMHSs.
5. Based on comparison among different models, provide feedback to GPCs about the models performance
6. Blend GPCs forecasts based on standard MME techniques as an additional guidance to GPCs, NMCs, and RCCs, among other existing multi-model products.
7. Provide dynamic web pages to satisfy requirements for regional display of forecast information (e.g. regions used by RCOFs)
8. Redistribute digital hindcast/forecast data for those GPC's that allow it.
9. Handle requests for the password for the website and data distribution; maintain a database recording the users who have requested access to data/products and the frequency of access
10. Maintain an archive of the real-time GPC and MME forecasts

The GPCs proposed a phased approach in the development of the activities of the Lead Centre for LRFMME and they were agreed as follows:

•*Phase 0*: Lead Center maintains a repository of GPC forecast system configurations

•*Phase 1:* GPCs provide data for predicted anomalies for selected variables on a monthly basis and the Lead Center generates forecast plots for all GPCs and displays them in a common format on a website (with password protected access only for GPCs, RCCs and NMCs). These plots will be additional information/tools for GPCs to produce their final product

•*Phase 2*: GPCs provide hindcasts and real-time forecasts (raw data). Anomalies for individual GPC forecasts will be computed at the LC-LRFMME and displayed in a common format. The LC-LRFMME could also compute anomalies based on various well established MME schemes and display the MME forecasts in the same common format as used for the GPC forecasts.

Any distribution of GPC digital data will depend on predetermined agreement with the relevant GPC.

•*Advantages of Phase 1 & 2:*

–Users will have access to different forecasts to create their own final forecast guidance

–GPCs will have assessments of the strengths and deficiencies of their own models, providing input/motivation to model developers

–Promotes further development of MME techniques

–There will be increased cooperation between GPCs on LRF

–The data sets from all different hindcasts will be a great asset for applied research (e.g., predictability; atmospheric response to different boundary conditions).

Workshop participants also recommended that the CBS ET-ELRF should act as the advisory body for the functions of the Lead Center for LRFMME.

There was consensus within the participants that no change was required at the moment to the SVSLRF. The SVSLRF should be applied 'as is' to the outputs of MME in an identical way as for the individual models. However, the participants recommended examining the relevance of level 3 of the exchange.

Workshop participants considered issues of promotion related to GPCs and agreed there was need for more promotion of GPCs products already available to all NMHSs. The GPCs recommended that WMO secretariat sent a letter explaining the newly available products to all NHMSs and other relevant regional institutes

The participants congratulated KMA for its undertaking on LRF and encouraged the KMA Seoul and NCEP Washington to continue the hard work for seeking LC-LRFMME recognition at next CBS.

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REPORT OF THE WORKSHOP OF GLOBAL PRODUCING CENTRES ON LEAD CENTRE FOR LONG-RANGE FORECAST MULTI-MODEL ENSEMBLE PREDICTION

Busan, 18-20September 2007

Opening

1. A Workshop of Global Producers of Long Range Forecasts was held, at the kind invitation and support of the Republic of Korea, in Busan from 18 to 20 September 2007. Twelve participants representing the 9 GPCs and Moscow as future new GPC attended the workshop (see Annex I). The programme of the workshop can be found in Annex II. The workshop was opened Tuesday 18 September 2007 at 9.30 a. m., together with the APEC Climate Centre Symposium, by Dr Man-Ki Lee, permanent Representative of the republic of Korea with WMO. Dr Man-Ki Lee recalled the importance of Climate Prediction, and that Seoul and Washington were committed to develop the activities of a Lead Centre for Long-Range Forecast Multi-Model Ensemble prediction, and that it was also important to share information for the benefit of all countries.

1.1 The WMO Secretariat representative, Mr Joel Martellet, expressed the gratitude and appreciation of WMO to the Government of the Republic of Korea and its Permanent Representative with WMO, for the kind invitation to host and support this workshop of Global Producing Centres of Long Range Forecasts (LRF). He also thanked all the staff of Korea Meteorological Administration who helped with the planning and arrangement of the excellent facilities for the event, especially, the Director-general, Mr Yun-Ang Chung, the Director of Climate Prediction, Dr Won-Tae Yun, Dr Jeong Eun Kim and Dr Ja Yeon Moon. The WMO representative stressed that this workshop should be a forum for constructive and serious discussions between the GPC representatives, first to exchange the status, the scientific advances or the problems for the production and verification of global long range forecasts, but the main goal of the workshop, given the fact that multi-model ensemble prediction systems provide more reliable forecasts compared to single model ensembles, was to discuss how to organize, through the service of a leading centre, a useful operational exchange of the long-range forecast products that can facilitate the construction of a multi-model ensemble comprising the individual ensembles from the GPCs. He recalled that the objective of the workshop was to achieve definition of the procedures and the standards for the exchange (which data, which format), to define the policy for access to products, the verification methods to be applied and the products and information to be made available to National Meteorological Services and Regional Climate Centres. He stressed also that ultimately, one of the WMO roles is to ensure that long-range forecast products are fully used to provide predictions to WMO members countries (that is their National Meteorological Services) to contribute to disaster prevention and mitigation (e.g through information on drought or flood risks), and to contribute to better social-economic planning that accounts for variable climatic conditions.

WMO CBS AND CONGRESS STATEMENTS

2. The WMO representative gave a presentation placing the production of LRF in the context of the Global Data Processing and Forecasting System of the World Weather Watch and the recommendations and statements made by CBS Ext. 06 and Congress XVth.

LONG-RANGE FORECASTING AT CBS EXT. 06

CBS Ext. 06 made the following statements and recommendations related to LRF, GPCs and Multi-Model Ensemble for LRF.

2.1 In the *Manual on the GDPFS* the designation of RSMCs with activity specialization includes "long-range weather forecasts" (products). The Commission agreed that an explanatory note be added in the *Manual* to clarify this reference in relation to GPC of LRF (Vol. I, Part II, paragraph 1.4.1.2 (b)). The recommended amendment is given in Annex III (Annex 2, Part 1 to draft Recommendation 6.3/1).

2.1.2 The Commission recommended that the criteria for designating a Global Producing Centre of Long-range Forecasts (GPC of LRF) and the list of designated GPCs be added to the Manual as a new section (Vol. I, Part II, APPENDIX II-8). The recommended amendment is given in Annex III.

2.1.3 The Commission agreed that the "Minimum List of Products to be made available by GPCs", as included in the Appendix II-6 of the Manual on the GDPFS be revised to include some necessary clarifications without any change to the minimum list of products. These products should be made available to as many NMCs and Regional Climate Centres (RCC) as possible, for the purpose of enabling them to perform their tasks. The recommended amendment to the Manual on the GDPFS is given in Annex III (Part 3 to draft Recommendation 6.3/1).

2.1.4 The Commission noted data or products in addition to those required in the minimum list of products could also be provided by GPCs on request by RCCs or NMCs; the RCCs and NMCs would adhere to conditions, if any, attached by the GPCs to these data and products. This additional list is given in the Annex IV.

2.1.5 The Commission agreed to recognize, after considering their achievements, the list of designated GPCs to be included in the *Manual on GDPFS* as GPCs of LRF:

2.1.6 The Commission agreed the use of multi-model ensembles (MME) for long-range forecasting (LRF) is worthwhile since:

- MMEs provide the opportunity for improved reliability over that available from single model ensembles alone;
- MMEs provide the opportunity to estimate uncertainties in LRF, and to particularly identify limitations of LRF;
- MMEs provide a means to a "confidence builder" in the area of LRF; and
- Larger improvements in skill can be achieved from the use of MMEs.

2.1.7 The Commission agreed that some GPCs of LRF could serve as collectors of global LRF data to build MMEs. Such centres could perform the following functions:

- Collect global hindcasts and forecasts from participating GPCs and make them available to other GPCs, Regional Climate Centres (RCC) and NMHSs, as registered users (with password protected access);
- Promote the exchange of research and experience on MME, and provide documentation on MME;
- Work at the establishment of standards for MME products;
- Provide a repository of different MME techniques for the generation of MME in support of GPCs and RCCs; and
- Provide display of GPCs forecasts in a common format based on agreed standards, to RCCs, NMCs and GPCs, with password protected access.

CONGRESS XVth AND LONG-RANGE FORECASTING

2.2 Following CBS Ext. 06 report and Members contributions, Congress made the following statements related to LRF.

GPCs

2.2.1 Congress appreciated that CBS-Ext.(06) (Seoul, November 2006)) recognized nine official GPCs that meet the requirements for GPCs, including an agreed minimum list of global LRF products. Congress encouraged other centres producing global LRF to work at achieving the criteria for GPC designations.[1] *(see note 1 below)*.

2.2.2 Given the anticipated improvements in skill of LRF by using a multi-model ensembles (MME) approach, Cg-XV agreed that some GPCs of LRF could serve as collectors of global LRF data to build MMEs, and requested standards for MME products be developed. Cg-XV noted that ECMWF is already disseminating MME products based on Met Office, Météo-France and ECMWF LRF model output (EUROSIP) and that GPC Seoul and GPC Washington have agreed to explore the use of MME for LRF.[2]*(see note 2 below)*.

Climate products

2.2.3 Congress also noted the importance of delivering climate prediction products using common formats, and urged Members, GPCs, CCI and CBS to work together to define and implement these. In addition, ongoing coordination is required to ensure that operational products from the GPCs meet the requirements for seasonal forecasting services provided by RCCs and NMHSs.

WORK PLAN AND GENERAL DISCUSSION

3. The workshop participants decided to nominate Dr Richard Graham, chairman of the new CBS Expert Team on ELRF, to act as chairman for leading its work and general discussion. The participants agreed to the programme of work as indicated in Annex II.

3.1 The nine GPCs and Moscow presented the status of their operational activities and current development. Their presentations are summarized in Annex V. An overall trend among the GPCs is the increase (or planned increase) in the resolution of their models, as well as the number of members and the introduction of additional models to generate the ensemble. Several GPCs have been using the multi-model approach for sometime and currently some GPCs are issuing operational forecasts based on MME predictions.

3.2 The workshop participants before considering the functions of a new centre serving as collector of global LRF data to build MMEs, agreed to use for it the name "Lead Centre for Long Range Forecast Multi-Model Ensemble prediction (LC-LRFMME)". Then the main objectives of this workshop were considered:

- Review the status of development for Lead Centre for Long Range Forecast Multi-Model Ensemble prediction (LC-LRFMME)
- Refine needs for and functions of LC-LRFMME
- Propose recommendations related to LC-LRFMME tasks and GPCs role for LRFMME production and access/distribution of products.

ACTIVITIES TOWARDS A JOINT LEAD CENTRE FOR LONG-RANGE FORECAST (LRF) MULTI-MODEL ENSEMBLE (MME) PREDICTION:

3.3 The representative of GPC Seoul presented a report of the activities of the centre in the perspective of the implementation of a Lead Centre for LRFMME.

3.3.1 History

A meeting of the global producers of seasonal-to-interannual forecasts (long-range forecasts (LRF)) was held on 10-13 February 2003 in Geneva. A key topic of discussion was the important potential of LRF in forecasting extreme events from an operational production perspective. Their conclusions included that emphasis should be placed on ensemble prediction. A Workshop of Global Producers of Long Range Forecasts was held in Ramada Plaza Hotel in Jeju Island Korea from 10 to 14 October 2005. Twenty participants representing operational Long-range Forecast producers and two regional centres attended the

[1] Moscow has just entered the process of seeking recognition for GPC
[2] In that context, the Republic of Korea had proposed to host a Workshop, with all GPCs' representatives, on Lead Centre for Long-Range Forecast Multi-Model Ensembles (LC-LRFMME) in Busan from 18 to 20 September, in parallel with an APCC meeting.

workshop. Participating GPCs believed there was a significant need for a Lead Centre to collect LRF data and to display them in a standard format in order to facilitate the construction of LRFMME products. The Korean Meteorological Administration (KMA) suggested the need for a “Global Lead Centre of LRFMME” within the framework of WMO. Participating GPCs recommended that WMO established procedures and standards for Lead Centre for LRFMME. Participating GPCs appreciated the offer by KMA to become a Lead Centre for LRFMME within the framework of WMO, and recognized the considerable experiences of KMA in the area of LRF and LRFMME construction. The offer of KMA was recognized again at the 14th session of WMO CCI meeting held on 3-10 November 2005, Beijing, China. At the WMO Workshop of GPCs on LRF held in Jeju, Korea, from 10 to 14 October 2005, the KMA, in collaboration with the APEC Climate Centre, suggested a need for a "Lead Centre for LRFMME". The GPCs have recognized the importance of coordinating activities in order to progress the development of LRFMME. The Commission for Climatology of WMO also noted the suggestion and the importance of such modelling activities to seasonal prediction.

At the Meeting of the Joint Expert Teams on Long-Range Forecasting (Infrastructure and Verification) held on 3-7 April, 2006, ECMWF, the team appreciated the offer by KMA, possibly joint with NCEP (USA), to become a Lead Centre for LRFMME. The Team agreed to a set of functions for a Lead Centre for LRFMME at this meeting. At the CBS (Commission for Basic Systems) Extraordinary session held in Seoul, Korea, from 9 to 16 November, 2006, the Commission took note with appreciation of the intentions by KMA (Republic of Korea) and NOAA (USA) to commence work collaboratively as collectors of global LRF data toward meeting operational requirements for Long-Range Forecast Multi-Model Ensemble predictions, with a view to become “Lead Centre” in this field. The Commission encouraged Global Producing Centres (GPCs) for Long-Range Forecasts to exchange their seasonal hindcast and forecast data, and to provide them to centres pursuing LRFMME predictions, in particular to GPC Seoul and GPC Washington to facilitate development work as soon as possible. The Commission requested the OPAG on DPFS to further refine and clarify the functions of Lead Centre for LRFMME predictions for possible official recognition of such Centres regarding its achievements, at next CBS session in 2008.

3.3.2 Current status of LRFMME and needs of LC-LRFMME

Current Ensemble Prediction Systems mostly use a single model with a set of perturbed initial conditions to take account of the analysis uncertainty. This approach essentially ignores uncertainties in the formulation of the forecast model and assumes that forecast uncertainty is due only to initial condition errors. Different models generally have different formulations (and different biases). MME systems use essentially a statistical combination (weighted by past performance) of the forecasts of different models to take account of uncertainties due to model formulation and thereby obtain, in general, a more reliable forecast than from a single ensemble.

Since nine GPCs for Long-Range Forecasts (LRFs) were officially recognized at CBS Extraordinary session (Seoul, Korea, 9 - 16 November 2006), it would be useful if all GPCs share their outputs with all regions, but GPCs’ products were not fully used because of the different standards. Many operational GPCs have different methods, skills, data formats, display graphics formats, issuing times, initial conditions, boundary conditions, and integration methods. Similarly to the role of the Lead Centre of Standardized Verification System (SVS) for LRF, the Lead Centre for LRFMME is needed, to act as a coordinator of GPCs in LRF data production. MME techniques improve reliability over that available from single model ensemble alone. When GPCs’ products are combined by the Lead Centre for LRFMME, the uncertainties associated with seasonal and long-range predictions will be better estimated. By pooling forecast information from the GPCs, the LC-LRFMME will make an important contribution to improving the resources available for disaster prevention and mitigation, and for better social-economic planning that accounts for variable climatic conditions.

Recently, KMA has developed nonlinear MME prediction system based on genetic algorithm. This system shows better score than that of simple ensemble mean.

3.3.3 Role of RCCs and GPCs

It would ease the Regional Climate Centres (RCCs) tasks if GPCs could converge in forecast formats, issuance times, etc. Clear guidelines would be required for this, and to outline the roles and the responsibilities of GPCs with respect to RCCs. Also establishment of a clearing house for all available GPC products would help efficient transfer of forecast data to RCCs.

RCCs were considered under the following fields; operational activities, regional coordination, data services, training and capacity building, research and development, and GPC coordination. RCCs desire that the GPCs continue activities in the following areas: improving LRF skill, focusing on the main forecast parameters required by the RCCs; provision of data products; conducting further research into improving forecast skill, and developing new forecast products. New products should be developed in close collaboration with scientists from RCCs and NMCs.

3.3.4 Goal and functions of Lead Centre for LRFMME

Improved LRF will help to reduce the socio-economic losses associated with seasonal variability, and protect life and property. With this in mind, the Lead Centre for LRFMME will have as its main goal the pooling and sharing of GPCs forecast information in order to increase the reliability of LRF. Future roles of the Lead Centre for LRFMME under the framework of WMO will be development of MME techniques and exchange of GPCs LRF products. The Joint Expert Team on LRF agreed to a set of functions for a Lead Centre for LRFMMEs and the Team recommended that the Commission for Basic Systems propose the recognition of Lead Centres for LRFMME, once the required functions have been developed.

3.3.5 Related Activities

KMA constructed a proposed form for the website of a Lead Centre for LRFMME at http://www.wmolc.org. This website introduces the status of Lead Centre for LRFMME and provides a data exchange system and repository of MME techniques. Access to data exchange system is restricted to authenticated users.

Currently, KMA is developing next generation MME prediction technique that can extract nonlinear signal from the dataset based on a genetic algorithm. KMA is planning to develop further innovative MME prediction techniques by collaboration with APEC Climate Center, NCEP (USA) and many experts in climate prediction.

3.4 GENERAL DISCUSSION

The workshop participants considered the functions of the Lead-Centre for LRFMME and proposed phases in the development of its activities. They considered a schedule of activities, phases, tests and pilot exchanges. The participants also considered the format of the LC-LRFMME products, how to make these products available to users, and how to manage access to the products and data exchange (e.g. passwords and distribution rules for passwords).

Revised functions of the Lead Center:

3.4.1 The tasks of the Lead centre were reviewed and there was a consensus to refine the list of functions of the Lead Centre for LRFMME as follows:

1. Maintain a repository of documentation for the system configuration of all GPC systems
2. Collect hindcast and forecast data from GPCs
3. Display GPCs forecasts in standard format
4. Promote research and experience in MME techniques and provide guidance and support on MME techniques to GPCs, RCCs and NMHSs.
5. Based on comparison among different models, provide feedback to GPCs about the models performance
6. Blend GPCs forecasts based on standard MME techniques as an additional guidance to GPCs, NMCs, and RCCs, among other existing multi-model products.
7. Provide dynamic web pages to satisfy requirements for regional display of forecast information (e.g. regions used by RCOFs)
8. Redistribute digital hindcast/forecast data for those GPC’s that allow it.
9. Handle requests for the password for the website and data distribution; maintain a database recording the users who have requested access to data/products and the frequency of access
10. Maintain an archive of the real-time GPC and MME forecasts

Phases:

3.4.2 Possible Schedule/Milestones:

The GPCs proposed a phased approach in the development of the activities of the Lead Centre for LRFMME and they were agreed as follows:

•*Phase 0*: Lead Center maintains a repository of forecast system configurations on a web site (e.g., hindcast period; ensemble size; resolution; couple/tier-2; URLs; data availability; Points of Contact)

•*Phase 1:* GPCs provide data for predicted anomalies for selected variables (Nino indices; surface temperature; precipitation) on a monthly basis. The Lead Center generates forecast plots for all GPCs and displays them in a common format on a website (with password protected access only for GPCs, RCCs and NMCs):

–These plots will be additional information/tools for GPCs to produce their final product
–LC-LRFMME could also provide plots for special requests (e.g. from RCOFs)
–LC-LRFMME could also display simple plots conveying the degree of consistency among the GPC forecasts

•*Phase 2*: GPCs provide hindcasts and real-time forecasts (raw data)

–Anomalies for individual GPC forecasts will be computed at the LC-LRFMME and displayed in a common format (using e.g. common hindcast calibration periods)
–the LC-LRFMME could also compute anomalies based on various well established MME schemes (eg. equal weights; skill based regression) and display the MME forecasts in the same common format as used for the GPC forecasts. As for the Phase 1, these plots become additional information/forecast tools for GPCs, RCCs and NMCs to produce their final product
–The LC-LRFMME will compute consistent SVSLRF skill estimates for MME products generated by LC-LRFMME and provide them to the Lead Centre for SVSLRF
–If agreed upon, other GPCs can access the digital data and produce their own final (in-house) guidance. This data could be distributed by the Lead Center on a common grid/format.

•*For both Phase 1 and Phase 2*

–Any distribution of GPC digital data will depend on predetermined agreement with the relevant GPC
-Only basic graphical products (e.g probabilities for tercile categories) will be displayed, using data products equivalent to essential products (as defined in Manual on GDPFS (Appendix II.6))
-Graphical forecast products displayed will be accompanied by caveats stating that they are not official WMO forecasts, nor do they represent the final official forecast for any country or region as produced by the NMS or RCC for that country or region.

•*Advantages of Phase 1 & 2:*

–Users will have access to different forecasts to create their own final forecast guidance
–GPCs will have assessments of the strengths and deficiencies of their own models, providing input/motivation to model developers
–Promotes further development of MME techniques
–There will be increased cooperation between GPCs on LRF
–The data sets from all different hindcasts will be a great asset for applied research (e.g., predictability; atmospheric response to different boundary conditions)

Workshop participants also recommended that the CBS ET-ELRF should act as the advisory body for the functions of the Lead Center for LRFMME.

4. SUB-GROUP DISCUSSIONS

Workshop participants agreed to create two separated sub-groups and approved the nomination of two leaders to discuss the following issues:

SUB-GROUP (1) HOW TO ORGANIZE THE EXCHANGE OF PRODUCTS***** *(leader: Dr Won-Tae Yun)*
Agenda guide for sub-group1:

- –The products to be collected by LC-LRFMME (parameters, levels, anomalies, probabilities, etc.…)
- –Format of the products to be collected by LC-LRFMME (standard, volume,…)
- –Mean of exchange (Internet, ftp, CD?…) and frequency, time of exchange
- –Data period (Hindcasts/Forecasts)
- ◆* *Ensure that necessary products access and exchanges are respecting restrictions defined by various countries data policies e.g. requested confidentiality, embargo policies, etc*

SUB-GROUP (2) *(leader: Dr David Jones)*
Agenda guide for sub-group 2:

- –STANDARDIZATION OF VISUALIZATION
  - ✦1 Diagrams to be produced with standard regions
  - ✦2 Diagrams to be produced with time-average
  - ✦3 Format of the diagrams in horizontal map
- - ACCESS TO LC-LRFMME PRODUCTS
  - - Data exchange policy

The conclusions of the sub-groups are listed below and all the workshop participants reviewed them in plenary and agreed to pass them as recommendations to be examined by the next ET on ELRF, with a view to their approval by the next CBS.

4.1 CONCLUSIONS OF SUB-GROUP I

Dr. Won-Tae Yun
Jean-Pierre Ceron
Dr Laura Ferranti
Dr. Arun Kumar
Dr Vladimir Kryzhov
Takayuki Tokuhiro

4.1.1 How to organize exchange of forecast data

1. Member GPCs should provide hindcast and forecast data to the lead center (a staged approach is recommended, i.e Phase I and II)
2. Consult all GPCs to establish the latest date in the month by which forecast data should be provided
3. Data distribution policy to be reviewed through the WMO process (for the next ET meeting)
4. GPCs to provide phase 1 data as soon as possible before the end of December 2007. The schedule for phase 2 provision will be decided later.
5. Data to be provided to the Lead Centre by internet file transfer
6. The frequency of provision will be monthly (i.e. the same as the forecast issue frequency for most GPCs)

4.1.2 Data to be provided to the lead center by GPCs

4.1.2.1 For Phase I Data*:*

- Provide monthly ensemble mean anomalies for:
    - (a) Surface (2m) temperature
    - (b) Sea Surface temperature
    - (c) Total Precipitation Rate [kg m^{-2} s^{-1}]
    - (d) Mean Sea Level Pressure [hPa]
    - (e) 850hPa Temperature [K]
    - (f) 500hPa geopotential height [m]

4.1.2.2 For Phase II Data: Hindcast + Forecast

- Monthly means of individual members:
    - o Same variables as for Phase 1, with the possibility of additional variables
- For the hindcast period refer to the SVSLRF document (a minimum of 15-years of retrospective forecasts)

Format of the forecast/hindcast data

(a) Spatial resolution: 2.5°(lat.) x 2.5°(long.) over global domain (144 x 73 grids)
(b) Temporal resolution: Monthly Mean
    (average from the 1st day through the end day of the month)
(c) Writing order: Eastward from 0° to 2.5°W, Southward from 90°N to 90°S
(d) Format: GRIB-2 format is highly recommended but GRIB-1 is temporarily acceptable
(e) Lead Time: 0-4 months for seasonal forecast

4.2 CONCLUSIONS OF SUB-GROUP 2

Dr David Jones
Mr Normand Gagnon
Dr Richard Graham
Dr Jeong-Eun Kim
Dr JaYeon Moon
Dr Peiqun ZHANG

4.2.1 Standards of data and visualization products

The recommended temporal resolution, lead-times, variables and update frequencies for images are those prescribed for GPCs in Annex 2 of Recommendation 6.1/3(CBS-Ext.(06)) (see Annex III of this report).

- All images and data are to be provided with metadata following the appropriate WMO/ISO standard.

- Forecast-types displayed will be (asterisk denotes 'quick-time' products developed from Phase 1 data):
    - averages or accumulations over 3-month periods
    - ensemble-mean anomalies* (*Note: In Phase 1 GPC favoured climatology (which may vary with GPC) will be used).*
    - above/below median probabilities
    - tercile category probabilities
    - Nino region monthly SST anomaly plumes

- Anomalies and quantiles will be calculated by the Lead Centre for each individual model using a hindcast period common to all GPCs.

- Displayed forecast periods will be:
    - the 3-month period following the month of issue, using the latest available forecast from each GPC.

-Displayed geographical regions will be:

- Globe
- Northern extratropics
- Southern extratropics
- Tropics
- Nino regions (for SST plumes)

- Individual GPC products
  - Forecasts for individual GPCs will be displayed in common graphical format in a way that allows comparison

- Multi-model products
  - Model consistency products (e.g. proportion with positive / negative ensemble mean anomaly, percentage with upper tercile most likely)
  - Equal weighted multi-model combination
  - More complex multi-model combinations may be added

- Appropriate disclaimers should be attached to the Multi-Model products indicating that they are not official WMO, NMS or RCC products, but produced only for guidance.

4.2.2 Access to GPC data and visualization products held by the LC-LRFMME

- A list of recognized GPC forecast users, eligible for access, will be defined (by WMO) and maintained by the Lead Centre (e.g. GPCs, RCCs, NMHSs, institutions hosting RCOFs such as ACMAD, ICPAC).

- Potential new users not belonging to the above categories may request access from WMO, who will refer the request to the designated GPCs. Decisions to allow access must be unanimous. The Lead Centre will be informed of new users accepted for access.

- The list of eligible users will be reviewed by the GPCs, to measure the degree of effective use and also to review any changes in status of eligible users. The GPCs and the LC-LRFMME will report on the review to the ET on Extended and Long-range Forecasting.

- Access to GPC visualization products on LC-LRFMME website:
  Access to visualization products will be by website password.

- Access to GPC digital data held by LC-LRFMME:
  Digital GPC data will be only re-distributed in cases where the GPC data policy allows it. In other cases, requests for GPC output should be referred to the relevant GPC.

- Digital multi-model products, from which the individual GPC data cannot be easily retrieved, may be distributed by the LC-LRFMME.

5. IMPLICATIONS FOR VERIFICATION

Workshop participants considered issues of verification related to GPCs activities, as well as implications for the work of the LC-LRFMME.

It was decided by the participants that there was not a need for a specific sub-group discussion on “Verification and Promotion”. These themes were discussed during the workshop in general and here is a summary of the relevant points.

5.1 Recommendations on verification:

-There was consensus within the participants that no change was required at the moment to the SVSLRF.

-The SVSLRF should be applied 'as is' to the outputs of MME in an identical way as for the individual models. However, the participants recommended examining the relevance of level 3 of the exchange (as defined in Attachment II-8 to the Manual on the GDPFS).

-On the SVSLRF web site the results coming from MME should be displayed together with the GPCs individual models and clearly be identified. The new LC-LRFMME will be responsible for submitting the different levels of the SVS exchange once relevant MME techniques are approved by the ET on ELRF.

-Every time a new MME technique is available and the LC-LRFMME wants to use it in an official way the performance of the new MME forecasts should be evaluated using the SVSLRF on hindcast data.

-The two Lead Centres (LC-LRFMME and LC-SVSLRF) should coordinate to make sure that forecast (hindcast) data received by the LC-LRFMME from a GPC is made by the same forecast system for which scores were submitted to LC-SVSLRF web site. The participants recognized that in practical terms this condition may not be easy to fulfill during implementation of a new forecast system by GPCs.

-There should be direct links between the LC-SVSLRF and LC-LRFMME web sites, connecting forecast maps and verification graphics for each GPC. The forecasts from each GPC may be readily viewed together with skill assessments, and vice versa.

- With regard to the above, the formats for the SVSLRF score exchange should be adjusted according to decisions reached for the LRFMME forecast data exchange (i.e. the regions and parameters displayed should be the same).

5.2 A review of the actual participation to the SVSLRF exchange was presented during the workshop:

- The following GPCs had submitted all the required scores of the levels 1 and 2 of the exchange:
  - *BCC, JMA, Météo-France, NCEP* and *MSC*

- *UKMO* had submitted almost everything (except maps of MSSS and its decomposition terms)
- *BOM* had submitted everything but ROC area maps and the diagrams (ROC or reliability diagram) because the ensemble run in hindcast mode has not enough members to do so.
- *KMA* had submitted just the maps associated with the MSSS and its decomposition maps.
- *ECMWF* had submitted to the SVSLRF web site just the aggregated scores (level 1). The rest of the scores is on their web site.
- *IRI* (not yet a GPC) had submitted every thing but the level 2 maps (ROC area, MSSS, etc.).

The GPCs that had not submitted all the required levels 1 and 2 data were kindly invited to do so as soon as possible. The Lead Centre of SVSLRF will appreciate to receive new relevant data from the official GPCs.

6. DISCUSSION ON PROMOTION

Workshop participants considered issues of promotion related to GPCs and LC-LRFMME activities and agreed to the following statements:

-There was need for more promotion of GPCs products already available to all NMHSs. Many GPCs have prepared in 2006 products for NMHSs to meet the requirements of becoming a GPC recognized by CBS. The recognized GPCs felt that these products were not sufficiently advertised to NMHSs.

-The GPCs recommended that WMO secretariat sent a letter explaining the newly available products to all NHMSs and other relevant regional institutes (e.g. ACMAD, ICPAC, DMC Harare).

-The promotion of the LC-LRFMME web site can be targeted to WMO Regions through CCI/CLIPS focal points.

7. CLOSURE OF THE WORKSHOP

The participants congratulated KMA for its undertaking on LRF and encouraged the KMA Seoul and NCEP Washington to continue the hard work for seeking LC-LRFMME recognition at next CBS. And all the participants thanked the Republic of Korea and KMA for the excellent hospitality and support provided, and for the excellent organization and work of the staff of KMA making a successful workshop. Dr Richard Graham was also thanked for his good and diplomatic leadership for discussions. The workshop was closed at 13.00 on Thursday 20 September 2007.

ANNEX I

LIST OF PARTICIPANTS

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ANNEX II

WMO/KMA GPCS WORKSHOP ON LEAD CENTRE FOR LONG-RANGE FORECAST MULTI-MODEL ENSEMBLE

(Busan, Republic of Korea, 18~20 September, 2007)

PROGRAMME

Tuesday 18 September		APEC Hall & Rm. 206, BEXCO
08:30~09:20	***Registration* (Only to APCC symposium participants)**	
09:20~10:20	Opening with APCC annual symposium	With APCC Symposium
10:20~11:00	Group Photo / Coffee Break	
11:00~12:00	Keynote Lectures (In-Sik Kang / Upmanu Lall)	
12:00~13:30	*Lunch*	
13:30~15:15	- Nominate Chair/Leader - Recall of related CBS Ext. 06 decisions *(Joël martellet)* - GPC Activities (Beijing, ECMWF, Exeter, Seoul, Montreal, Melbourne, Moscow, Tokyo, Toulouse, Washington)	
15:15~15:30	*Coffee Break*	
15:30~17:15	- GPC Activities *(continuation)*	
18:30~20:30	*Welcome Reception*	Capri Room, Paradise Hotel

Wednesday 19 September		Rm. 206, BEXCO
09:00~09:30	GPC Activities *(continuation)*	
09:30- 10:30	- Lead Centre Activities Review purposes and services expected of LC-LRFMME	
10:30~10:50	*Coffee Break*	
10:50~12:00	Subgroup meeting	*Group 1: Work at the establishment of standards for MME (I) *Group 2: Work at the establishment of standards for MME (II) *Verification and Promotion
12:00~13:30	*Lunch*	
13:30~14:40	*Subgroup meeting*	
14:40~15:00	Coffee Break	
15:00~17:15	*Subgroup meeting*	

Thursday 20 September		Miami Room, Paradise Hotel
09:00~10:30	Report of Rapporteur of each subgroup	
10:30~10:50	*Coffee Break*	
10.50 -13.00	General discussion and seek agreed consensus - to the function definitions of Lead Centre(s) for LRFMME - to recommendations and proposals for commitments from all the GPCs.Summary/Conclusions Closing	

Pragmatic analysis by 2 SUB-GROUPS (with Leader-Rapporteurs) based on the general tasks of Global Collectors of LRFMME defined by CBS:

SUB-GROUP 1: Work at the establishment of standards for MME products (1)

1. HOW TO ORGANIZE THE EXCHANGE OF PRODUCTS
   - 1.1 The products to be collected by LC-LRFMME
   - 1.2 Format of the products to be collected by LC-LRFMME
   - 1.3 Mean of exchange and frequency, time of exchange
   - 1.4 Data period (Hindcasts/Forecasts)

SUB-GROUP 2: Work at the establishment of standards for MME products (2)

1. ACCESS TO LC-LRFMME PRODUCTS
   - 1.1 Data exchange policy
2. STANDARDIZATION OF VISUALIZATION
   - 2.1 Diagrams to be produced with standard regions
   - 2.2 Diagrams to be produced with time-average
   - 2.3 Format of the diagrams in horizontal map

* Ensure that necessary products access and exchanges are respecting restrictions defined by various countries data policies e.g. requested confidentiality, embargo policies, etc? *(taking into account the concern raised at CBS by the United Kingdom regarding data policy and for the control of the forecast message to governments, key users and the media)*

VERIFICATION OF LRFMME PRODUCTS
   - 1.1 Verification datasets of observation
   - 1.2 Verification method
   - 1.3 Functions of promotion and information

Annex 2 to Recommendation 6.3/1 (CBS-Ext.(06))

PART 1

B. <u>Long-Range Forecasts</u>

B.1 Recommended amendment (new) to Vo. I, Part II, paragraph 1.4.1.2 (b)
Add following note :

1) Centres producing global long-range forecasts, and recognized as such by CBS, are called Global Producing Centres for Long-range forecasts (GPCs). The criteria to be recognized as a GPCs and the list of official recognized GPCs can found in APPENDIX II-8.

PART 2

B.2 Recommended amendment (new) to Vol. I, Part II, APPENDIX II-8

In order to be officially recognized as a GPC (Global Producing Centre of Long-range forecasts), a centre must as a minimum adhere to the following criteria:

- Fixed production cycles and time of issuance;
- Provide a limited set of products as determined by the APPENDIX II-6 of this Manual;
- Provide verifications as per the WMO SVSLRF;
- Provide up-to-date information on methodology used by the GPC;
- Make products accessible through the GPC Web site and/or disseminated through the GTS and/or Internet.

Centres that are designated as Global Producing Centres for Long-range Forecasts are listed below: Beijing, Exeter, Melbourne, Montreal, Seoul, Tokyo, Toulouse, Washington and ECMWF.

PART 3

B.3 Recommend amendment (revised) to Vol. I, Part II, APPENDIX II-6

“Minimum list of LRF products to be made available by global scale producing centres”

Forecast Products

Note: it is recognized that some centres may provide more information than the list including for example daily data or hind cast data.

Basic properties

<u>Temporal resolution</u>.
.
Averages, accumulations or frequencies over 1-month or longer periods (seasons)

<u>Spatial resolution.</u>
2.5° x 2.5° (note: selected to match resolution of current verification data)

<u>Spatial coverage.</u> **Global**
(separate areas of interest to users, down to sub-regions of a continent or ocean basin, may be provided on special request from Members)

<u>Lead time.</u> **Any leadtimes between 0, and 4 months (**definition of lead time: for example, a three-monthly forecast issued on 31 December has a lead time of 0 months for a January-to-March forecast, and a lead time of 1 month for February-to-April forecast, etc.)

<u>Issue frequency.</u> **Monthly or at least quarterly**

Output types. Either rendered images (eg forecast maps and diagrams) or digital data.. GRIB-2 format should be used for products posted on FTP-sites or disseminated through the GTS.

Indications of skill including hind cast **should be provided**, in accordance with recommendations from CBS on the Standardised Verification System (Attachments II-8). The minimum required is level 1 and level 2 verification. The verification of Nino3.4 index will only apply to those centres producing such indices. However GPCs are encouraged to provide level 3 verification. Verification results over the hindcast period are mandatory.

Content of basic forecast output: (some products are intended as directly meeting NMS requirements with regard to information needed for end-user applications [direct or further processed]; others are to assist the contributing global centres in product comparison and in the development of multimodel ensembles. These products are regarded as feasible from current systems).

A. **Calibrated outputs from ensemble prediction system showing the mean and spread of the distribution for:**
   - **2 metre temperature over land**
   - **sea surface temperature**
   - **precipitation**
   - **Z500, MSLP, T850**

   Note: - These fields are to be expressed as departures from normal model climate.

B. **Calibrated probability information for forecast categories.**

   - **2 metre temperature over land**
   - **SST (Atmospheric coupled models only)**
   - **Precipitation**

   Notes:
   (1) B **is the minimum requirement. A should be provided, at least, by request.**
   (2) **Tercile categories should be provided**, consistent with present capabilities. Information for larger numbers of categories (e.g. deciles) is foreseen, however, as capabilities increase and to match better the anticipated end-user requirements. These targets are implied also for forecasts from statistical/empirical models.
   (3) **Information on how category boundaries are defined should be made available.**
   (4) "Calibrated" implies correction based on systematic errors in model climatology, using at least 15 years of retrospective forecasts.

ANNEX IV

The Commission noted data or products in addition to those required in the minimum list of products could also be provided by GPCs on request by RCCs or NMCs; the RCCs and NMCs would adhere to conditions, if any, attached by the GPCs to these data and products. This additional list is given below:

Other LRF Data and Products from GPCs

1. **Experimental products desired by users of GPC outputs:**
    - Averages, accumulations or frequencies over 1-month period to 3-month period.
    - Probabilities of exceeding some threshold values (e.g., seasonal rainfall totals above a range of thresholds).
    - Risk of extreme climate anomalies that may help in warning of e.g. occurrence of heat and cold waves over a particular region.
    - Predicted generalized indices of drought, monsoon etc.
    - Dry and wet spells: frequency and duration (with one month lead time).
    - Probable date of onset of main rainy seasons (over a region, like South Asia, East Asia, southern Africa, GHA etc).
    - The need to have first month (0-lead) averages was expressed.

2. **The GPV (grid point value) products are preferred in GRIB 2 format rather than NetCDF, especially for downscaling. The requirements are as follows:**
    - Forecast data for downscaling algorithms; this is likely to require more than monthly mean data, e.g.:
        - Statistics on daily variability
        - Anomalies for some or all ensemble members
    - Hind cast data
    - Data for RCM boundary and initial conditions (including SST data).
    - Data for calculating regional specialized indices (drought).
    - Analyzed fields of surface and upper air parameters for use in empirical models as predictors.
    - Observed and predicted global weekly values of SST.
    - Daily satellite precipitation analysis for use in monitoring through the season.

3. **Regional climate centres/NMCs may not have expertise in all aspects of Long-range forecasts. They will need assistance in training from GPCs in the following main areas:**
    - Interpretation and use of GPC LRF products.
    - Downscaling techniques (both statistical and dynamical).
    - Verification techniques (for local verification of RCC generated products and application outputs).
    - Development of local user applications from RCC downscaled products.
    - Use and implementation of regional climate models.

ANNEX V

LIST OF CENTRES RUNNING OPERATIONALLY LRF NUMERICAL MODELS (14 CENTRES)

REGION I

CENTRE	*STATUS*	*MODELS*	*RESOL.*	*LEVELS*	*RANGE*
PRETORIA	Geo. RSMC	GM (COLA) 10 ens. – LAF - Persisted SST	T30	L28	8 months

REGION II

SEOUL	NMC	GM GDAPS Ens. 20 members, BGM, 2 tiers system	T106	L21	1 month 3 months 6 months
BEIJING	Geo. and Transport Model (T.M.) RSMC	GM DERF Ens. 40 members 16 SV, 16 LAF coupled, Ocean	T63 GT63	L16 L30	1 month
		GM Ens. 48 members LAF coupled 8 atmo x 6 oceano cond.(perturb ocean) Ocean	T63 GT63	L16 L30	Season
TOKYO	Geo.- T.M. and T.C. RSMC	GM Ens. 50 members 25 BGM and 25 members LAF on 2 days	T106	40	34 days
		GM Ens. 51 members, SV, 2 tiers for SST	T63	40	4 months

REGION III

LIMA	NMC	CCM3 Coupled Ens. 12 members, perturbed SST (from USA)	T42	L32	9 months
INPE/CPTEC -SAO PAULO	Special Centre	GM Coupled, Ens. 30 members (Random OP) Fixed and predicted SST	T62	28	6 months

REGION IV

IRI (USA)	Special Centre	Ens. multi-models, over 30 members, LAF			6 months
MONTREAL	Geo. and T.M. RSMC	GM Ens. 40 members (24 h LAF, four models)	1.875° T32	50 10	9 months
WASHINGTON	WMC, Geo. RSMC, T.M. RSMC	Ens. 20 members, (GFS) coupled, Modular Ocean Model ,MOM 3, LAF	T62 1/3-1deg.	64 40	7 months

REGION V

MELBOURNE	Geo. and T.M. RSMC	Ens. 10 members, GM coupled (POAMA), LAF	T47	17	9 months

REGION VI

ECMWF	RSMC for Medium-Range	GM System 3 (IFS) Ens. 50 members SV+StoP, coupled with HOPE (Hambourg Ocean Primitive Equation), 29 levels , 5 ocean OI analyses with SST perturbation	T159	62	10 days to 1 month
		GM (IFS) Ens. 41 members OP+StoP, coupled with HOPE, 29 levels , 5 OI ocean analyses with SST perturbation	T159	40	13 months
TOULOUSE	T.M. RSMC	GM (ARPEGE-Climat) Ens. 10 members – LAF Coupled OPA8.2	T63	31	129 days
		GM (ARPEGE-Climat) Ens. 41 members – LAF Coupled 8 atmos. X 5 ocean initial stes	T63	31	16 months
EXETER	Geo. and T.M. RSMC	GM Had CM3 Glosea Ens. 41 members, coupled, OI ocean, 40 random OP of SST	Atm2.5° Ocean: 1.25°	19 40	6 months
MOSCOW	WMC, Geo. RSMC	GM Ens. 10 members, two-tier, OI ocean, Semi-Lagrangian AGCM..	1.125°/ 1.40625°	28	4 months

PRESENTATIONS OF GPCs

Status of Activities as a Global Producing Centre for Long-Range Forecasts in Beijing

Long-Range Forecast and Related Products, Capacity Building and Training
National Climate Center (NCC, Beijing Climate Center), China Meteorological Administration
Submitted by
Peiqun Zhang (zhangpq@cma.gov.cn)

Operational Long-Range Forecast

- Monthly(30-day) forecast
  - Dynamical approach
    - Based on its monthly dynamical extended range forecast model (DERF), NCC runs its DERF model and issues the monthly (30-day) global prediction in the first day of every pentad, i.e., 1st, 6th, 11th, 16th, 21st and 26th, with 40 members at most. The prediction displays special for Asia and China, besides global, for the period of next 1-10day, 11-20 day, 21-30 day and 31-40 day, 1-30 day and 11-40 day ensemble mean forecast. The variables include the precipitation, 2-meter temperature, geopotential height at 200hPa, 500hPa and 700hPa, sea level pressure, zonal and meridional wind at 200hPa and 700hPa levels. The temperature and precipitation forecasts are issued both in determined way by ensemble means and probabilistic way by 3 terciles.
  - Statistical approach (China only)
    - Based on its monthly statistical model (including CCA, Analog Analysis, Regression, etc), NCC issues its Monthly Climate Prediction of the whole China before the end of each month for the coming month to all the Region and Province Meteorological and Hydrological Services of China. The prediction basically consists of the anomalies of precipitation and temperature, as well as some climate conditions relevant to special agricultural activities, for instant spring sowing, etc.

- Seasonal (3-month) climate prediction
  - Dynamical approach
    - Based on its coupling general circulation model (CGCM), NCC real time forecast is released around 25th each month for following 0-6month (2 seasons future), which are produced from initial conditions near the end of the previous month. Total number of forecast ensemble members is 48, using 8 atmospheric initial conditions and 6 oceanic initial conditions. The 8 atmospheric initial conditions are taken from each of the last 8 days of the end of previous month. The 6 oceanic initial conditions are from a single initial state with different perturbations of ocean data assimilation system. The variables of products include the precipitation, 2-meter temperature, 500hPa geopotential height, 850hPa temperature, sea surface temperature. The temperature and precipitation prediction are issued both in the determined way by ensemble means and the probabilistic way by 3 terciles.
    - Monthly updated plumes for Nino3.4 index are displayed from the SSTA prediction too.
  - Statistical approach
    - Based on its seasonal statistical model (mainly focus on prediction of summer and winter, including CCA, Analog Analysis, Regression, Physical Concept Model etc), NCC issues its Flood Season Climate Prediction at early April for the coming summer, and Annual Climate Prediction at late October for the coming winter and next spring to all the Region and Province Meteorological and Hydrological Services of China. The prediction basically consists of the anomalies of precipitation and temperature.
- East Asian Monsoon Prediction
  - The tendency of onset and intensity of East Asian Monsoon are outlook based on some major impact factors and Physical Concept Model at early April and then updated monitoring.

- The ENSO Report
  - An operational overview of the status of El Niño/La Niña, based on latest forecasts and observation, irregularly issued as per ENSO evolvement, and made available in publishing and through the web. Contributions to the WMO EL Niño alerts
  - In addition dynamical forecast by CGCM, the output from a suit of statistical model for ENSO forecast are considered as ensemble reference.

The data and documents for required skill measures were submitted to the Lead Centre of SVS in 2006.

All of this information can be accessed at NCC and BCC websites: http://ncc.cma.gov.cn and http://bcc.cma.gov.cn. And efforts are ongoing to enhance and improve the capability of the websites in displaying products and data access.

Capacity Building and Training

Two Projects are ongoing in NCC for improving the operational capacity on monthly and seasonal forecast. One is a CMA project, named Application of Output from Dynamical Climate Model on Regional Climate Prediction Project, leading by NCC and through partnership with Regional and Province Meteorological Services in China. The project aimed at improving the application of NCC model output at regional level of monthly forecast based on the downscaling tool. The other named Ensemble Method on Short-term Climate Prediction is a subproject of a state supporting program on numerical model development and its application, aiming at applying multi-initial-condition and multi-model ensemble to improve the skill of seasonal prediction over East Asia.

National Climate Center (Beijing Climate Center) has hosted there sessions of the Forum on Regional Climate Monitoring-Assessment-Prediction for Regional Association (FOCRAII) in Beijing, sponsored by CMA and WMO. In the latest session in 2007, there are totally 102 participants from 24 countries/territories or regional groupings and representatives of the WMO, CIIFEN (Ecuador) and ICPAC (Kenya). Besides providing seasonal prediction of NCC dynamical model to the participants during forum, training on seasonal forecast and application on products of NCC climate model are delivered to participants.
The products or outputs of NCC dynamical climate model are provided to APCC and some other countries and used in their seasonal forecast, for example Nepal, Pakistan, etc.

Future Plan: 3-5 years.

It has commenced on the development of next generation BCC Climate System Model (BCC_CSM) since 2005. This system is being developed as an integrated modelling system for LRF through to climate change time predictions. Model components are being ported from the NCAR (Atmospheric Model and Assimilation) and GFDL and IAP (MOM4 Ocean Model, Sea Ice Model and IAP Land Surface Model, AVIM). It is planned that this modelling system will launch into real-time operational service in approximately 2-3 years.

Summary of Long-range forecast production at the Met Office: systems, products, and verification

Richard Graham, Hadley Centre, Met Office, UK, September 2007

The Met Office produces dynamical global real-time operational long-range predictions for up to 6-months ahead. The forecasting system is based on a version of the Hadley Centre climate model, HadCM3, specially adapted for seasonal forecasting purposes and known as 'GloSea' (details are available at www.metoffice.gov.uk/research/seasonal). GloSea is run in a 41-member ensemble on the ECMWF super computer and forms one component of the developing European multi-model (EUROSIP) along with, currently, the ECMWF system3 and the Météo France seasonal forecast models. Initial conditions for the GloSea ensemble are generated from a mix of windstress perturbations applied during assimilation and instantaneous SST perturbations. Atmospheric and land-surface initial conditions are taken from the ECMWF operational analysis.

The real-time forecasts are calibrated using a set of retrospective predictions (hindcasts) run in a 15-member ensemble over a 15-year period 1987-2001. Forecasts are generated each month with products made available on the website in the last week of each calendar month. A user guide to the products, forecast methods and verification methods, and a user feedback questionnaire are also provided. The Met Office has been designated a WMO GPC, and as such issued website products conform to those required in Appendix II-6 of the WMO Manual on the GDPFS, and include:

- one-month-average SST anomaly plumes for the Niño3, Niño3.4 and Niño4 regions
- global maps of probability for tercile and outer-quintile categories of 3-month-average 2m temperature, precipitation, temperature at 850 hPa, pmsl and 500 hPa height. Forecasts for a variety of geographical regions (eg as used for RCOF region consensus forecasts) are also provided.
- maps of predicted ensemble mean, and summary maps showing information on the most likely tercile categories are also provided.
- multi-model products, derived from an 80-member ensemble of the GloSea and ECMWF system3 models, are also shown.

Verification is provided for GloSea temperature and precipitation products for the globe and all forecast sub-regions following the scores and procedures specified in the WMO standard Verification System for Long-range Forecasts (SVSLRF). Verification is calculated over the 16-year period 1987-2002 using ERA40 and GPCP for verification of temperature and precipitation, respectively. The skill measures provided for probability forecasts are ROC and reliability curves (level 1 of the SVSLRF) and maps of area under ROC curve (level 2 of the SVSLRF). Verification of deterministic forecasts currently comprises a Gerrity score assessment for forecasts of the most likely tercile category.

In addition to the GloSea and EUROSIP forecasts, products using a number of statistical/empirical methods are also generated and, where benefit has been found, combined objectively with the GloSea dynamical model output. These products are made available on the website and also disseminated to a number of users. They include forecasts for: the March-April-May wet season in NE Brazil; the July-August-September wet season over tropical North Africa (including the Sahel) and the October-November-December short rains over East Africa. Statistical/empirical methods are also used to generate European summertime (July-August) temperature forecasts and forecasts of the winter North Atlantic Oscillation (NAO) index.

An operational forecast statement on the prospects for winter 2005/6 over the Europe/UK region was issued in August 2005 using forecaster-combined results from a statistical prediction of the NAO index, the GloSea dynamical model prediction, and monitoring of the observed evolution of North Atlantic surface and subsurface temperatures. The forecast was widely used in government and, following requests, forecasts are now issued for all seasons with monthly updates within the season.

Following encouraging verification results indicating that GloSea forecasts of North Atlantic season tropical storm frequency can outperform corresponding statistical predictions, the first GloSea prediction for North Atlantic tropical storm frequency over the July to November 2007 period was issued on the Met Office website in June 2007.

A new development in 2007 has been the first business application of decadal range forecasts using the Met Office decadal prediction system (DePreSys), a version of HadCM3. Estimations of annual mean temperature were provided to 2011 as part of a business consultancy with the energy industry.

Customers for long-range forecasts include:
- National Meteorological Services and other users including the Regional Climate Outlook Fora, DMC Harare and ICPAC Nairobi
- UK government departments
- The general public
- Business consultancy, including a number of commercial customers working in the weather derivatives, energy supply and trading, oil industry, utilities and retail sectors.
- A seasonal forecast for water volume inflow into Lake Volta, Ghana, developed as an aid for management of the Akosombo dam hydro-electric power facility.

Key of future development include:
- Implementation of the new Met Office climate model HadGEM as the next seasonal forecasting system (2009).
- Research to improve model representation of seasonal modes of variability, with a focus on the Europe/UK region
- Improved seasonal model data assimilation techniques, and implementation of stochastic physics.
- Further development of decadal range forecast products
- Exploration of methods to calibrate and verify seasonal forecast systems without reliance on long hindcasts (to allow implementation of optimal model configurations, they may be make long hindcasts prohibitively expensive).

Activities as a Global Producing Centre for Long-Range Forecasts in Melbourne

Australian Bureau of Meteorology

September 19 2007

Dr David Jones (d.jones@bom.gov.au)

Operational Long-Range Forecast Products (publicly available)

- Sea-surface temperature forecasts from the Predictive Ocean Atmosphere Model for Australia (POAMA) coupled atmosphere-ocean general circulation model (version 1).
  Daily updated plumes for NINO 1, 2, 3, 3.4 and 4.
  Daily updated spaghetti diagrams/anomalies/Hovmollers for sea temperature anomalies.
  Daily updated histograms of likely anomalies, providing probabilities of warm/neutral/cool conditions in the Pacific.
- 3-month seasonal climate outlook products (Australia only).
  Rainfall, maximum and minimum temperatures.
  Extensive hindcast verification and forecast validation of all outlook products.
- Contributions to the WMO EL Niño alerts and other international collaborations (NZ ICU, APCC).

All of this information can be accessed at the following two websites:
http://www.bom.gov.au/climate
http://www.bom.gov.au/bmrc

Operational Long-Range Forecast Products (available on request)

- Surface (e.g., rainfall) and upper level fields (e.g., T850) from POAMA1.
  9-month forecasts updated daily.
  Products in a standard format – NetCDF. Can be convert to GRIB etc as needed.
- Extensive hindcast verification results are available and a range of technical and scientific reports have been written. Verification performed following the SVSLRF.

All products are calibrated relative to the model's climate calculated as a function of lead-time and start month, using hind-casts. The current website is http://www.bom.gov.au/bmrc/ocean/JAFOOS/POAMA.

"Experimental" Long-Range Forecast Products (available on request)

- Surface (e.g., rainfall) and upper level fields (e.g., T850) from POAMA1.5b.
  9-month forecasts updated daily.
  Products in a standard format – NetCDF. Can be convert to GRIB etc as needed.
- Extensive hindcast verification results are available and a range of technical and scientific reports have been written. Verification performed following the SVSLRF.

All products are calibrated relative to the model's climate calculated as a function of lead-time and start month, using hind-casts. The current website is http://poama.bom.gov.au . Gridded forecasts and hindcasts are available via openDAP server.

Capacity Building and Training

Pacific Island Climate Prediction Project (PICCP)

An Australian Bureau of Meteorology – Australian AID (AUSAID) project delivered through partnership with Meteorological Services in Fiji, Tuvalu, Tonga, Samoa, Cook Island, Nuie, Kiribati, Solomon Islands, New Guinea and Vanuatu. Seen the development of a PC based "*down-scaling*" tool for delivering tailored Seasonal Climate Outlooks for Pacific Island Countries called SCOPIC (Seasonal Climate Outlooks for Pacific Island Countries).

Australia is exploring, in collaboration with other Pacific countries, the various options for implementing a distributed system for providing climate information, including Long-Range forecast material, throughout the Pacific. These matters are being taken up within the contexts of various bi-laterals and the WMO Regional Climate Centres framework.

Summary of the GPC activities for GPC Montreal

Normand Gagnon
Busan workshop September 18-20 2007

Update on the current system:

- MSC produces deterministic and probabilistic seasonal forecasts for both precipitation and temperature for the Canadian area since 1995.
- A new system will be implemented in Fall 2007. This system uses 4 differents dynamical models including the RPN GEMCLIM and CCCma AGCM3 with 10 members per models, to build a 40 member ensemble.
- MSC will then begin to provide one month lead time seasonal forecasts as well as the usual zero lead time.
- Better performance (reliability and signal detection) with this new system is expected following verification on a 35 year hindcast (see Figure 1 below). The hindcast was performed following the SMIP2-HFP protocol.
- The expected skill at forecasting seasonal precipitation anomalies remains low even with the new improved ensemble.

MSC's experience as an official GPC:

- A new password protected web site that shows global maps of temperature and precipitation forecast categories (deterministic and probabilistic) is available to all NMHs. The address of the web site is:

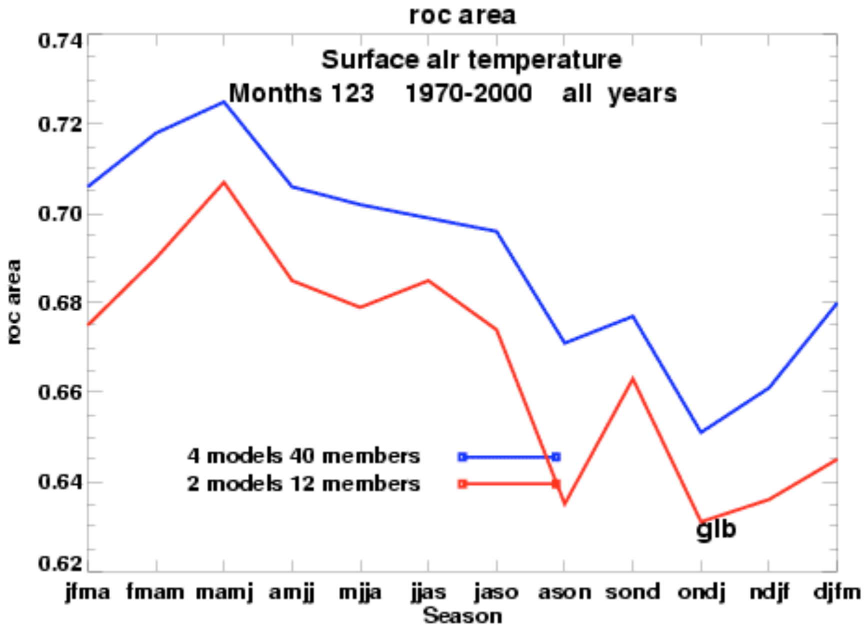
http://collaboration.cmc.ec.gc.ca/cmc/saison/glb/cmc_seasonal_fcst_global.html

- NMHs can get the login and password to look at the forecast on this site in sending a request at the email address: "implementation@ec.gc.ca"
- A FTP site where user can find monthly means for several fields in GRIB1 is linked to the new web site. The hindcast data is available as well.
- MSC only got one demand on international level since its recognition as an official GPC: summer forecast for the PRESAO area by Richard Graham in May 2007.
- Very few demands were received by NMHs to grant the access to this new web site. We fell the more promotion should be done.
- All levels 1 and 2 of the SVSLRF exchange are displayed on the LCSVSLRF web site for the actual Canadian system.

MSC's experience with MME:

- MSC strongly believe in MME of dynamical models to do seasonal forecasting. Twelve members from two models are used operationally since 1995 to issue the 0-3 month forecast.
- Following a study made using the Best Unbiased Linear Estimator technique (Derome et al. 2001, *Atmos-Ocean*). MSC found that model weighting using skill level is a big challenge with the availability of only relatively short hindcast period (26 years). A simple arithmetic average (equal weights) of the individual model ensemble mean gives equivalent or better results than the BLUE technique.
- To build a super ensemble a better approach might be to correct individually models and to blend the corrected fields using arithmetic averaging (increase the robustness of the system as well when one model forecast is missing).

a)



b)

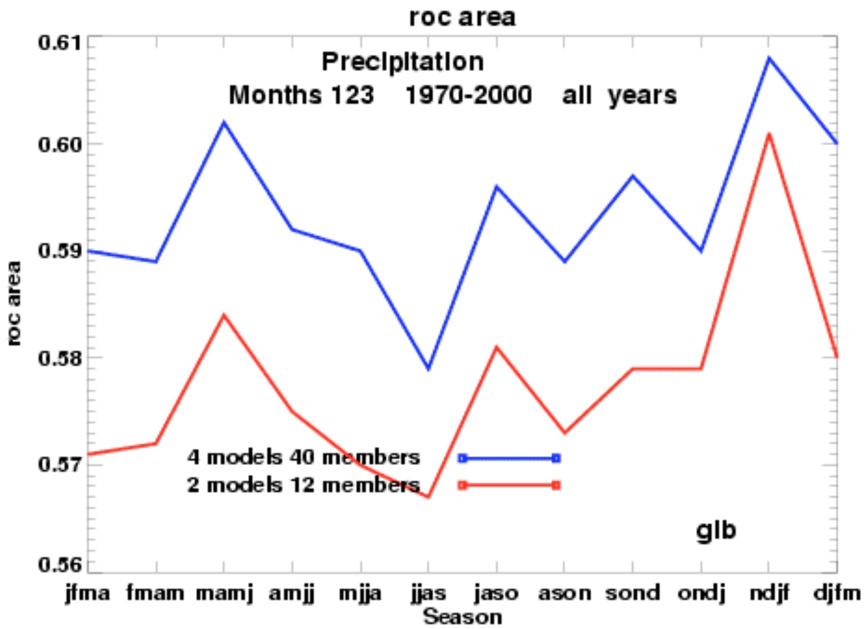


Figure 1: Mean global ROC score in function of the 12 rolling 3 month season for the average of the 3 categories performance during a hindcast covering the period 1970-2000. The top and lower panel shows ROC score for the surface air temperature (a) and precipitation (b) anomalies. The verifications were made using the CRU2.1 data sets which include surface station observations over land only. The blue lines illustrate the performance of the new 4 model system while the red ones the performance of the current 2 model system.

Global Producing Centre - Moscow
Host Institute: Hydrometeorological Research Centre of the Russian Federation (HMC RF)

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SUMMARY
OF THE ACTIVITIES AS A GLOBAL PRODUCING CENTRE
FOR LONG-RANGE FORECASTS

Model: Semi-Lagrangian Atmospheric Model with 1.125/1.40625 degrees lat/lon horizontal resolution and 28 sigma levels
(For details, see the attached file HMC_LRF_model.doc)

1. Operational LRF Products

1.1. Global forecast for 3 months of the variables listed in Table 1.
Lead time: zero
Temporal Resolution: 1 month
Schedule of issuing: monthly, the day preceding the forecast period
Usage: operational practice of LRF Division of HMC RF - supporting forecast
Internet: -

1.2. Global Seasonal (calendar season) forecast of the variables listed in Table 1.
Lead time: approximately 1 month
Temporal Resolution: 1 month
Schedule of issuing: seasonally, the early dates of the month preceding to calendar season: early February, May, August, November
Usage: operational practice of LRF Division of HMC RF and NEACC (North Eurasia Climate Centre) - supporting forecast; operational practice of APCC (APEC Climate Center, Busan, Korea)
Internet:
(1) Forecast of T850 and Precipitation is available at the web sites of HMC RF (http://wmc.meteoinfo.ru) and NEACC as global and North Eurasia seasonal forecast maps of probabilities of tercile categories, with the forecast maps being accompanied with the maps of RSS (ROC Skill Score) and the maps of significance level of RSS;
(2) The whole set of variables (Table 1) is available at the APCC web site (www.apcc21.net) as monthly and seasonal forecast maps in terms of bias-corrected anomalies, with the whole set of associated deterministic forecast verification scores (SVS) being provided.

Note: model calibration (bias correction) is based on the 25 year (1979-2003) SMIP-2/HFP hindcast.

2. Near Future Plans

2.1. Expand of Operational LRF

2.1.1 Global forecast for the first of 3 months (Item 1.1) will be posted on the HMC RF web site (from October 2007), lead time will be extended to about 1 month.

2.1.2. Global forecast for 3 months with 1 month lead time (now it is confined to calendar seasons - item 1.2) will be issued monthly (from October 2007)

2.2. Verification scores provision

2.2.1. Provision of SVS verification scores for SVS Lead Centre – Melbourne (late 2007)

2.3. Development of the MME

2.3.1. Development of the two-model (HMC RF – MGO) one-three month prediction system

2.3.2. Development of the MME seasonal prediction system (in cooperation with APCC)

2.4. Capacity Building and Training

2.4.1. Training Course on Regional Downscaling from MME Products for the LRF specialists of the NMHSs of Asia-Pacific (Korea, Russia, Thailand, the Philippines, Indonesia, Vietnam, New Zealand) is planned in cooperation with and on the basis of APCC (we have applied for 2008 APN funding).

Table 1. List of predicted variables

Data Type	2)	**Forecast (total)**		**Climatology**	
		Monthly	**Daily**	**Monthly**	**Daily**
Variable	**Surface (2m) air temperature [K]**	+	+	+	+
	Total precipitation rate [kg/m^{2}sec]	+	+	+	+
	Mean sea level pressure [hPa]	+	+	+	+
	850hPa Temperature [K]	+	+	+	+
	500hPa Geopotential height [m]	+	+	+	+
	850hPa Zonal velocity [m/sec]	+	+	+	+
	200hPa Zonal velocity [m/sec]	+	+	+	+
	850hPa Meridional velocity [m/sec]	+	+	+	+
	200hPa Meridional velocity [m/sec]	+	+	+	+

Korea Meteorological Administration (KMA)
Introduction to Long-Range Forecasting System and Activities

1. Forecasting System

1.1 System run schedule and forecast ranges

KMA produces three types of long-range weather forecasts: 1-month, 3-month (seasonal), and 6-month forecast. The 1-month forecasts are issued three times a month and include temperature, precipitation, and air pressure pattern for the next 30 days. The 3-month forecast which are produced at monthly basis include the trends of temperature, precipitation including special seasonal events such as Asian dust, Typhoon and Changma for the next 3 months. The 6-month forecast is issued twice a year (May and November). The system run schedule and products are listed in Table 1.

Table 1. Long range forecasting system run schedule and products.

	1-month forecast	3-month forecast	6-month forecast
Issue Date	· 3rd , 13th, and 23rd day of each month	· 23rd day of each month	· 23rd day of May and Nov.
Forecast type	Three type categories : above, below and near normal The anomalies are based on model's climatologies obtained from a 28 year database (1979 to 2006).		
Contents	· 10-day mean temperature and precipitation · 30-day mean temperature and precipitation	· 1-month mean temperature and precipitation · 3-month mean temperature and precipitation *[1]*Asian dust outlook* *[2]*Typhoon outlook* *[3]*Changma outlook*	· 1-month mean temperature and precipitation (Jun. to Nov./Dec. to May)
Forecast area	Temperature : whole Korea Precipitation : whole Korea	Temperature : whole Korea Precipitation : whole Korea	Temperature : whole Korea Precipitation : whole Korea

*[1]*Asian dust outlook* is issued in late February including frequency and density of Asian dust expected to affect Korea for the upcoming Spring.

*[2] *Typhoon outlook* is issued in late May and Aug. regarding number of Typhoon expected to affect Korea for the upcoming Summer and Fall.

*[3] *Changma outlook* is issued in late May regarding or duration and intensity of Changma *(monsoon).*

1.2 Extended range forecasts (10 days to 30 days)

For the extended range forecast system, KMA has been operating global climate model with predicted sea surface temperature (2-Tier system). To predict the global sea surface temperature as a boundary condition for the 2-tier system, the global ocean forecasting system has been developed as a combined system of dynamical and statistical models. The global long-range forecasting system, using global climate models, is also being developed, and the SMIP2/HFP-type climatology for each model is produced for removing model bias and improving predictability. Detailed information about the model climatology is given in Table 2. The official products of extended range forecasts are 3-categorical forecasts of temperature and precipitation over Korea (see Table 1).

Table 2. Description of SMIP2/HFP Experiment

SMIP2/HFP Experiment		
Experiment design		28-year integration(1979-2006) 4-month integration for each case
Ensemble member		20 ensemble members
Initial member		00, 06, 12 & 18Z of 5 days for each case
Initial condition	Atmosphere	NCEP/NCAR reanalysis (U,V,T,q,Ps)
	Land surface	Climatology
Boundary condition	SST and sea ice	Predicted SST using dynamical and statistical prediction model
	Etc.	Same as SMIP2

1.2.1 Global Climate Model

The operational extended forecasts system is based on the global spectral model, GDAPS (Global Data Assimilation and Prediction System) with horizontal resolution of T106 and 21 vertical levels of hybrid sigma-pressure coordinate. For the Ensemble forecasts, we utilize 20 ensemble members by lagged average method with about 15-day forecast lead-time (see Table 2). Detailed model description is summarized in Table 3.

Table 3. Detailed description for global climate model

		GDAPS (Operational model)
Major Physics	Cloud Convection	Kuo (1974)
	Land Surface & PBL	SiB; Yamada-Meller (1982)
	Radiation	Lacis & Hansen (1974) for SW, Roger & Walshaw (1966); Glodman & Kyle (1968); Houghton (1977) for LW
	Large scale condensation	Kanamitsu et al.(1883)
Dynamics		Three-dimensional global spectral model with hydrostatic primitive equations Hybrid sigma-pressure coordinate Semi-implicit method
Resolution		T106L21
Ensemble size		20 members
Sea Surface Temperature		Predicted SST anomaly
Land Surface Initial Condition		Observed Climatology
Model Climatology		SMIP2/HFP simulation (1979 to 2006)
Forecast range		1-month forecast 3-month forecast 6-month forecast

1.2.2 Global sea surface temperature forecasting system

The El Nino prediction system (Kang and Kug, 2000) is based on the intermediate ocean and statistical atmosphere model. The ocean model differs from the Cane and Zebiak (1987) model in the parameterization of subsurface temperature and the basic state. The statistical atmosphere model is developed based on the singular value decomposition (SVD) of wind stress and SST.

To reduce the uncertainty of initial field on the ENSO model, the breeding technique is applied. In the case of an ideal experiment, it works for better predictability, while for our El Nino prediction model, its effect is not so clear because it has weak nonlineality. Therefore, it shows some possibilities to contribute the improvement of predictability for the complicated future ENSO prediction using coupled GCM.

In order to improve the western Pacific SST prediction, KMA introduced the heat flux formula and vertical mixing parameterization to the ocean model. The initialization of the model is done by combining observed SST and wind stress. Wind stress is calculated by using the 925hPa wind of NCEP/NCAR reanalysis data. The method with calculated wind stress for initialization has a better forecast skill than that with FSU wind stress in recent predictions. (Kug et al., 2001). In addition, the present prediction is attended with random noise considered weather noise, and generates many sets of prediction. Our approach for random noise is similar to Kirtman and Schopf (1998).

Then, to correct the systemic error in the prediction model, the statistical model is also applied. The used Coupled Pattern Projection Model (CPPM, Lee and Kang 2003) is a kind of pointwise regression model, and the main idea of the model is to generate realization of predictions from projections of covariance patterns between the large-scale predictor field and regional predictions onto large-scale predictor field at the target year. By applying this model to the dynamic model results and compositing the results from both the dynamical and statistical models, the predictability over the tropical Pacific is improved than before.

To predict the whole global SST, a statistical global SST prediction system is being developed by combining Coupled Pattern Projection Model(CPPM), Lagged Linear Regression Method(LLRM), El Nino prediction model, and persistence method. In the tropical Pacific, predictions produced by El Nino prediction model are used, and in other regions the best results between CPPM, LLRM, and persistence are used. The LLRM is one of the point wise statistical model based on the lag relationship between the global SST and ENSO index and the optimal lag is selected by the hindcast process in the model. This is developed to determine predict the Indian SST prediction. Using this global ocean forecasting system, the boundary conditions for the global climate model are also produced.

1.3 Long range forecasts (30 days up to two years)

The long range forecast system is the same as the extended range forecast system described in section 4.6 except the forecast range. The official products of extended range forecasts are 3-categorical forecasts of temperature and precipitation over Korea for the upcoming 3 months (see Table 1).

For the long range forecasts, we also utilize the multi model ensemble (MME) technique which has been developed and operated by APEC Climate Center (APCC). The APCC collects the historical and real-time forecast data of 15 different models from 8 countries and constructs the automatic MME input data producing system. The APCC has developed various MME techniques for deterministic and probabilistic seasonal predictions. For deterministic forecast, three kinds of linear MME techniques are used, namely biased and unbiased simple composite, weighted combination of multi-models based on SVD, and MME with statistical corrections. For probabilistic forecast, three ranges are determined by ranking method based on the percentage of ensemble members from all the participating models in those three categories. Moreover, regional MME system version MME I-IV has been developed for Asian Monsoon region.

1.4 LRF data dissemination

Global prediction data and figures are accessible through the GPC_Seoul website at http://www.wmolc.org/~GPC_Seoul. The data page is password protected.

2. Verification of prognostic products

2.1 Annual verification summary

The seasonal forecasts are verified in terms of global and regional (i.e. East Asia) anomaly correlation of precipitation and 850hPa temperatures during each season (MAM, JJA, SON, and DJF). The anomaly correlations of the seasonal mean fields for the hindcast experiment period of 1979-2006 are listed in the Table 4.

Table 4. Anomaly correlation of 850hPa temperature and precipitation.

	MAM		JJA		SON		DJF	
	P	T	P	T	P	T	P	T
Global	0.062	0.231	0.040	0.189	0.086	0.167	0.122	0.221
East Asia	0.138	0.249	0.032	0.182	0.036	0.193	0.110	0.237

3. Plans for the future

Planned Research Activities in Long-range Forecasting

In order to make operational regional long-range forecasts available in 2009, both statistical and dynamical downscaling methods have been developed in cooperation with APEC Climate Center (APCC) and Climate Research Lab. in the National Institute for Meteorological Research. Based on basic analysis of regional climate and topography over Korea, the regional climate sectors will be divided into 3~5 areas.

4. References

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Zebiak, S. E., and S. C. Dolan, 1986: Experimental forecasts of El-Nino, *Nature*, **321**, 827-832

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Activities as a Global Producing Centre for Long-Range Forecasts at Japan Meteorological Agency (JMA)

1. Introduction

JMA's Ensemble Prediction System (EPS) for Seasonal Forecast is fully operational and the products from the EPS are routinely issued; one-month, three-month, and cold/warm seasonal forecasts. The products, which meet all the requirements listed in Appendix II-6 of the Manual on the GDPFS, are available to National Meteorological or Hydrological Servises (NMHSs) on JMA's Tokyo Climate Center (TCC) web-site.
http://ds.data.jma.go.jp/tcc/tcc/index.html.

2. JMA's EPS for Seasonal Forecast

Numerical ensemble prediction technique has been applied for all range of current operational seasonal forecasting in JMA; one-month, three-month, and cold/warm seasonal forecasts (Table1). An atmospheric model is integrated for the prediction period under the specified SST anomalies. The outline of JMA's EPS for seasonal forecast can be accessed at JMA's TCC web-site.
http://ds.data.jma.go.jp/tcc/tcc/products/model/outline/index.html

The first application of numerical ensemble predictions in JMA is made in the one-month numerical forecast, which started in March 1996. Numerical ensemble prediction system applied for the operational three-month forecast in JMA in March 2003, and then for cold/warm seasonal forecasts in September 2003.

Hindcast data are used for the calibration and verification of seasonal forecasts. The 5-member hindcasts of the one-month forecast has been run for the period 1982-2001, and the 11-member hindcasts of the three-month and cold/warm seasonal forecast for the period 1984-2005.

Table 1 JMA's EPS for seasonal forecast as of Sep. 2007

Symbolic Name	One-month Prediction Model	Three-month Prediction Model	Warm and Cold Seasons Prediction Model
Specification	Atmospheric Model TL159(about 1.125º) and 40 vertical levels	Atmospheric Model TL95 (about 1.875º)and 40 vertical levels	Atmospheric Model TL95 (about 1.875º) and 40 vertical levels
Members	50 members	51 members	31 members
Operation	Once a week 34-day Forecast	Once a month 120-day Forecast	Twice a year (Feb. and Sep.) 210-day Forecast (Complementary forecast in Mar., Apr. and Oct.)
Issue Date	Every Friday	25^{th} day each month	25^{th} day of the above months

3. Dissemination of Forecast Products including Verifications

The grid-point-values (GPVs) and maps for one-month, three-month and cold/warm season forecast have been available to NMHSs on JMA's TCC web-site.

Several kinds of verifications, such as Reliability diagrams, Mean Square Skill Score (MSSS) and Relative Operating Characteristics (ROC), are also provided on TCC / JMA web-site. Verification data sets are the Japanese 25-year Reanalysis (JRA-25), GPCP, UKMO/CRU data, and so on.

JMA already complies with the WMO Standard Verification System for Long-Range Forecasts (SVSLRF) and submits the SVSLRF level 1 and level 2 verifications to the lead center for SVSLRF.

The products provided on TCC / JMA web-site already meet all the requirements listed in Appendix II-6 of the Manual on the GDPFS.

4. Future Implementation

JMA's EPS for Seasonal Forecast continues to be developed to improve forecast skill. In the near future, a coupled atmosphere-ocean model will be introduced to seasonal forecasts.

Summary of the GPC activities for GPC Toulouse

JP Céron – Direction of Climatology – Météo-France
Busan workshop September 18-20 2007

Information on the current system:

- MF produces operational deterministic and probabilistic seasonal forecasts using a fully coupled ocean atmosphere model. Probabilistic forecasts used the tercile categories and "extremes" categories (above + 1 stdv and below –1 stdv). The probabilistic forecast synthesis is also produced (more likely tercile category). Deterministic forecast is based on the standardised ensemble mean anomaly, the corresponding significance test and recalibrated ensemble mean anomaly (using stdv from "observation").
- Taking the opportunity of the computer change (moving from the FUJITSU VPP5000 to the NEC SX-8), the older forced version was left.
- The operational forecasting suite is distributed between Toulouse (ocean analysis and post-processing) and Reading (run of the model). The link between Reading and Toulouse for Seasonal forecasting is now secured (use of operational dissemination, Meteo-France operational data base, …).
- Main characteristics of the current system are 1 month lead-time, 6 month range and 41 members ensemble sampling both atmospheric and oceanic initial conditions.
- Date of issuance is the beginning of the month (commitment for the 8^{th}).
- Meteo-France seasonal forecast is part of the EURO-SIP production done by ECMWF.
- Hindcast is only over the 1993-2003 period and 5 members.
- Verifications are available via the LC web site. Additional verifications are available via the Demeter project evaluation web page.

Specific products:

- A global climate bulletin is issued by the end of each month and disseminated via anonymous ftp. The outlook uses several models. Taking the opportunity of multi disciplinary competences in Toulouse (Mercator, Cerfacs, CNRM and Climatology), one tries to analyse the behaviour of each model and then chooses the "more realistic solution(s)" (e.g. Nina forecast issued in May 2007). One also uses the Circulation Patterns to have some insight into consequences on regional temperature and rainfall.
- Developments have been done on downscaled products for New-Caledonia (South-West Pacific). The comparison between downscaled single model forecasts and downscaled multi-model forecasts (using the Demeter dataset) shows only slight improvement (cross-validation mode). MMEs seem to have clear interest mainly for large scale products. Finally, simulating short hindcast periods (15 years) the comparison between Perfect Prog methods and Model Output Statistics shows that the calibration of downscaling model using reanalysis dataset (PP method) is relevant in case of short hindcast period.

Use of products in the frame of WMO:

- Regular dissemination of forecasts : to Maghrebian NMHS, ACMAD, CIIFEN
- Niño update by WMO (Clips Office),
- Niño forecast synthesis by IRI,
- Global Bulletin (via anonymous ftp – same dissemination than forecasts),
- Participation to RCOFs and CLIPS (Presao, …),
- Additionally, real time application for a dam management in West Africa,

Future evolutions:

- New version of the forecasting suite schedule for the very beginning of next year:
  - atmospheric model : increase of vertical resolution (L91 instead of L31),
  - Oceanic model : free elevation at the surface
  - Oceanic assimilation : better assimilation scheme using altimetry and in situ observations, oceanic reanalysis over the 1979-2006 period,
  - Hindcast: 1979-2006 period, 11 members, 7 month forecasts
  - Operational: 41 members, 7 month forecasts, component of the Euro-Sip (new) system 3,
  - Verification: on the period 1993-2006, comparison with the existing system shows increased scores on rainfall, temperature (everywhere excepted North America) and geopotential height (notably for Europe – cf. Circulation regimes).
  -
- Developments already planned :
  - New products available : all lead-time, regional zooms (Tropics, Europe, …), post-processing of Circulation Regimes,
  - Verification bulletin associated with the Global Climate Bulletin,

U.S. National Weather Service's Climate Prediction Center (CPC)

The U.S. National Weather Service's Climate Prediction Center (CPC) maintains a suite of prediction products on seasonal-to-interannual time scales. These products include surface temperature and precipitation predictions over the U.S., and prediction for Niño 3.4 sea surface temperature (SST) index. The U.S. seasonal outlooks are generated in both text and graphical forms, and are for anomalous probabilities for the above-normal, below-normal, and near-normal categories.

The seasonal forecasts are generated based on inputs from multiple forecast tools that include empirical and dynamical methods. Dynamical seasonal forecasts are based on the dynamical seasonal prediction based on the National Centers for Environmental Predictions (NCEP's) Coupled Forecast System (CFS). CFS is run operationally at the NCEP and the current version has been operational since October 2004.

The atmospheric component of the CFS is the NCEP Global Forecast System (GFS) as of February 2003 with a horizontal resolution of T62 spectral truncation. There are 64 vertical levels in the atmospheric model with the top level at 0.2hpa. The oceanic component of the CFS is the GFDL Modular Ocean Model V.3. The domain of MOM3 is almost global extending from 74S to 64N. The meridional resolution of the ocean model is 1/3 between 10S and 10N, and gradually increases in the extratropical latitudes becoming fixed 1 poleward of 30S and 30N. The zonal resolution is 1. The CFS configuration of MOM3 has 40 layers in the vertical with 27 layers in the upper 400 meters. The vertical resolution is 10 meters from the surface to the 240 meters depth.

To establish model climatologies an extensive set of hindcasts is available. Hindcasts with CFS include a 15-member ensemble of nine month coupled forecasts run each month from 1982-2006. The real time forecast configuration includes twice-daily runs for 10 months, and forecast is constructed based on a 40-member lagged ensemble comprising of latest seasonal forecasts from past 20 days.

The data from hindcasts and the real-time forecasts is freely available. Instructions for downloading the model data can be found at:

http://cfs.ncep.noaa.gov

NCEP is in the process of upgrading its seasonal forecast system and the current estimate of the schedule upgrade is beginning of year 2010. This upgrade will involve following components:

1. A reanalysis from 1979-present involving same atmospheric and modeling components that will be used for the next update of the seasonal forecast system. This reanalysis will provide consistent initial conditions for hindcast and forecasts and will be completed in 2008.
2. A hindcast for from 1991-present and will be completed in 2009.
3. Finally, upgrade to the current seasonal forecast system in 2010.

ECMWF Seasonal Forecast activity

1. Introduction

ECMWF has been running a seasonal forecast system since 1997, and in March 2007 a new forecast system, known as System 3 (S3) was introduced. A system consists of the atmospheric and oceanic components of the coupled model as well as the data assimilation scheme to create initial conditions for the ocean, the coupling interface linking the two components and the strategy for ensemble generation.
New forecast systems are introduced only occasionally, both because of the work involved and the value of stability for users: System 1 (S1) became effectively operational in late 1997, System 2 (S2) started running in August 2001, and System 3 started running in August 2006 and became the operational version in March 2007. The atmospheric model for S3 is cycle 31r1 (Cy31r1) of the IFS. The horizontal resolution has been increased from TL95 to TL159 (with the corresponding grid mesh reduced from 1.875° to 1.125°), and the vertical resolution is increased from 40 levels to 62 levels, extending up to ~5 hPa. Major changes have taken place in the ocean analysis system for S3, though the HOPE ocean model is little changed from the version used in S2.

As in S2, the ocean initial conditions in S3 are provided not from a single ocean analysis but from a 5-member ensemble of ocean analyses, created by adding perturbations to the wind forcing used in the analysis. The atmospheric initial conditions, including land conditions, come from ERA-40 for the period 1981 to 2002 and from ECMWF operational analyses from 2003 onwards.

The real-time ensemble set consists of 41 members in S3, and the calibration set consists of 11 members spanning the 25-year period 1981–2005, so creating a calibration probability distribution function of 275 members. Each of these ensembles has a start date of the first of the month. The initial atmospheric conditions are perturbed with singular vectors and the ocean initial conditions are perturbed by adding sea surface temperature perturbations to the 5 member ensemble of ocean analyses. Stochastic physics is active throughout the coupled forecast period.

S3 seasonal integrations are 7 months long (S2 integrations were only 6 months). Additionally, once per quarter an 11 member ensemble runs to 13 months, specifically designed to give an “ENSO outlook”. Back integrations have also been made to this range, once per quarter, with a 5 member ensemble.

2. The ocean analysis

The ocean analysis for System 3 extends back to 1959 and provides initial conditions for both real-time seasonal forecasts and the calibrating hindcasts. Although only the ocean analyses from 1981 onwards are used directly in S3, the earlier ocean analyses will be used for analysing climate variability, and by the ENSEMBLES project for seasonal and decadal forecasts.

As for S2, the ocean data assimilation system for S3 is based on HOPE-OI (i.e. the optimum interpolation scheme developed for the Hamburg Ocean Primitive Equation model), but major upgrades have been introduced. In addition to subsurface temperature, the optimum interpolation (OI) scheme now assimilates altimeter derived sea-level anomalies and salinity data. There is also a multivariate bias-correction algorithm consisting of a prescribed a priori correction to temperature, salinity and pressure gradient, as well as a time-dependent bias term estimated on-line.

he improvements that assimilation make to the ocean initial conditions have a beneficial impact on the seasonal forecasts nearly everywhere, but especially in the west Pacific. Additional experiments have shown that the Argo array has a large impact on the analysed salinity field on a global scale, and leads to improved seasonal forecast skill (Balmaseda et al, 2007). A fuller description of the ocean analysis system can be found in Balmaseda et al. (2006).

3. Assessment of forecast skill

The starting point for a seasonal forecasting system is its skill in predicting sea surface temperature (SST). Comparing anomaly correlation and rms errors in forecasts of Nino 3, Nino 3.4 and Nino 4 SST from S3 with those from S1 and S2 shows clear progress. For example, Figure 1 shows the rms error for the Nino

3.4 index in S3 compared to the earlier operational versions S1 and S2. Over the last decade there has been sustained improvement in the ENSO forecast skill of our operational systems, although estimates of the predictability limit (not shown) suggest that there is still considerable scope for improvement. However, the strong improvement does not extend to all parts of the globe – outside the equatorial Pacific, changes in SST forecast skill are largely close to neutral, although there is a clear positive benefit in the north subtropical Atlantic.

The full range of verification statistics in line with the Standard Verification System for Long Range Forecast is available on the web for the previous system (S2) and shortly similar statistics will be completed for the new system (S3). The verification results (not shown) indicate that S3 is clearly improved in the tropics relative to S2. The situation in the mid-latitudes is less clear: NH scores over land appear to be slightly better in summer, but slightly worse in winter. Moreover, it seems that the strength of ENSO teleconnections to mid-latitudes is weaker in the model than in observations. Overall, forecast skill of atmospheric parameters does not demonstrate the clear progress that has been seen in El Nino forecast skill over the last ten years. Errors in the atmosphere models are still causing significant problems in our attempts to build reliable and capable seasonal forecasting systems.

4. Forecast products

With the implementation of the new seasonal Forecast System 3 in March 2007, the set of graphical products available on the ECMWF web site has been improved and expanded.

A summary of the changes recently introduced is as follows.
a) ***Entry page for the ECMWF forecast products*** www.ecmwf.int/products/forecasts

A new entry has been introduced for the System-3 ocean analysis (*Balmaseda et al.*, 2007), including maps from the real-time and the behind-real-time (BRT) analyses; both are used by the monthly forecast system (*Vitart*, 2003) and the latter by the seasonal forecast system (*Anderson et al.*, 2007). The BRT system is referred to as 'Re-Analysis', since it has been used to assimilate ocean data from January 1959 to the present.

b)***The seasonal forecast index page*** www.ecmwf.int/products/forecasts/d/charts/seasonal/forecasts

This page leads to three different sections devoted to the 'standard' seasonal-range forecast (run every month up to seven months ahead), the annual-range forecasts (run every 3 months up to 13 months ahead), and the EUROSIP multi-model ensemble made up from integrations of the ECMWF, Météo-France and UK Met Office coupled models.

c) ***The seasonal-range forecast page for System-3*** www.ecmwf.int/products/forecasts/d/charts/seasonal/forecasts/seasonal_range_forecast (available to WMO users)

This includes entries to the same four categories of products as in System 2, namely plumes for El Niño indices, horizontal maps of three-month anomaly statistics (ensemble mean and probabilities), climagrams (i.e. time series of indices representing area-averaged anomalies or teleconnection pattern amplitudes) and tropical-storm indices. However, all these sections have been improved, and forecast products have been extended to seven months following the increased length of the integrations. Additions include a new 'summary' plot of probabilities for tercile-based categories in the horizontal map section. There is a substantial expansion of the climagram section, now comprising area-averages of two-metre temperature and precipitation over 25 areas, extratropical teleconnection indices and rainfall-based monsoon. A set of real-time forecast products is released to the public on the ECMWF website at 12Z on the 22nd of each month - look for the "seasonal forecast" section under www.ecmwf.int/products/forecasts. A fuller description of the new seasonal forecast products is available in Molteni et al 2007.

5. Multi-model forecasts

S3 is part of the EUROSIP multi-model seasonal forecasting system. Currently, the participants in EUROSIP are ECMWF, the Met Office and Météo-France, but other members are expected to join in the future. A common operational schedule is followed, and data is held in a common archive at ECMWF, which facilitates production of multi-model forecast products. EUROSIP products are available on the web to the ECMWF Member States users.

6. Summary

Throughout the extensive development period of System 3 various atmospheric model cycles were tested as they became available. Progress was not monotonic. Although each cycle improved or was at least neutral for the medium-range forecasts this was not so for the seasonal forecast range, where new cycles sometimes led to a significant drop in skill. However, the last few cycles have resulted in strong and significant gains in SST prediction skill, and the model version used in System 3 is the best yet seen when assessed by its ability to predict El Nino SST variations in the Pacific.

System 3 still has clear deficiencies, however. Blocking in the northern hemisphere is not well handled, and the Madden-Julian Oscillation (MJO) is not well represented. Several other major features of System 3 should be highlighted. The ocean analysis/reanalysis is a major product in its own right. The increased ensemble size and the larger set of back integrations (25 years rather than 15 years) increase the accuracy of the forecast products. This is a big step forward for those wishing to process the model output themselves to create tailored seasonal forecast products. The new experimental ENSO outlook forecasts extending to 13 months give a longer-range outlook on one of the major factors that drives seasonal climate anomalies. There is still scope for substantial improvements in the future, but we hope that System 3 will be a useful step on the road to developing numerical systems that fully exploit the predictability that exists on seasonal timescales.

References

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Figure 1: RMS errors for Nino 3.4 SST forecasts from System 1 (dashed), System 2 (dotted) and System 3 (solid), for 192 forecasts in the common period 1987-2002. Results are for 5 member ensembles in each case. For reference, the upper dot-dash line shows the RMS error of persistence of anomalies.