WWRP 2008 - 4

Expert Meeting to Evaluate Skill of Tropical Cyclone Seasonal Forecasts

(Boulder, Colorado, USA, 24-25 April 2008)

World Meteorological Organization
Weather • Climate • Water

WMO/TD - No. 1455

Chairperson, Publications Board
World Meteorological Organization (WMO)
7 *bis* avenue de la Paix
P.O. Box No. 2300
CH-1211 Geneva 2, Switzerland

Tel.: +41 22 730 8403
Fax.: +41 22 730 8040
E-mail: publications@wmo.int

WORLD METEOROLOGICAL ORGANIZATION

WORLD WEATHER RESEARCH PROGRAMME

WWRP 2008 - 4

EXPERT MEETING to EVALUATE SKILL of TROPICAL CYCLONE SEASONAL FORECASTS

(Boulder, Colorado, USA, 24 – 25 April 2008)

Organized by the Tropical Cyclone Panel of the
WWRP Working Group on Tropical Meteorology Research

World Meteorological Organization
Weather • Climate • Water

WWRP WORLD WEATHER RESEARCH PROGRAMME

WMO TD No. 1455

TABLE OF CONTENTS

EXECUTIVE SUMMARY

This expert meeting was organized in response to the recommendations of the Sixth International Workshop on Tropical Cyclones to develop a common set of metrics to evaluate the skill of seasonal tropical cyclone forecasts and report on a central website hosted by WMO. Camargo et al. summarized in the October 2007 issue of the *WMO Bulletin* a number of statistical and dynamical seasonal forecasts. Representatives of each type of forecast were part of the expert team. Issues confronted when attempting to conduct an evaluation of forecasts produced by different groups include:

(a) Differences in lead times and temporal periods of the seasonal forecasts;
(b) Differences in spatial domains;
(c) Different approaches to provision of a measure of uncertainty (e.g., many groups do not currently provide an expected range, which will require a considerable conversion effort for most groups that currently provide probabilities); and
(d) Differences in the method of verification and benchmarking.

The common lead times and forecast periods in the various tropical cyclone basins are provided in Table 1 for the first (Level I) seasonal activity measure of the number of named storms during the season. Similar lead times and forecast periods will apply for the Accumulated Cyclone Energy (ACE) index (Level II) and for the number of hurricanes/ typhoons and the number of major hurricanes, which are the activity measures that are presently proposed for Level III. Whereas all groups are encouraged to develop ACE forecasts as an important measure of seasonal activity, not all groups will be expected to provide the proposed Level III forecasts. The common spatial domain for each basin (Figure 1) are generally identical to the WMO tropical cyclone region definitions with some combinations. Although the public or commercial groups desire an exact number of storms or hurricanes, providing a range about that forecast number will more properly inform the public as to the uncertainty in the forecast arising from various sources that limit the seasonal predictability of tropical cyclone activity.

In conjunction with the WMO/CAS/WWRP Joint Working Group on Verification (JWGV), skill measures are to be proposed that will qualify a technique to be entered on the WMO website and allow forecasters to compare various seasonal forecasts. The skill measure for these techniques is to be evaluated against the previous five-year mean for that forecast variable. Both the mean (or median) value and the range about the mean will be verified so that the reliability of the forecasts will be measured. As each season is completed, the basis for validating the number of tropical cyclones and their intensity evolutions will be determined from the post-storm (best track) analyses of the Regional Specialized Meteorological Centre. It is hoped that other researchers planning to submit a seasonal forecasting technique to the WMO website will utilize the open-source software statistical package called “R” when analyzing their forecasts.

The purpose of the WMO website is to provide a self-consistent set of seasonal tropical cyclone forecasts in as compact a format as possible. Links to the original forecasts will be provided for more detailed descriptions and for prediction parameters not evaluated on the WMO website. Veracity of the automated inputs to the website will be the responsibility of the providers of the forecasts. Minimal monitoring by WMO personnel is expected. A disclaimer should be

included that the WMO is not legally responsible for any actions taken in response to these forecasts.

Inclusion of information about each type of seasonal forecast and each technique is considered to be essential. That is, the website will have an educational role in the proper use of seasonal tropical cyclone forecasts as well as on the interpretation of the verification measures.

The prototype version of the WMO website will be developed in cooperation with Colorado State University and the NOAA Climate Prediction Centre forecasts for the Atlantic, and with the City University of Hong Kong forecasts for the western North Pacific. Data formats and forecast submission procedures and timelines that are worked out with these three groups will then be the standard for other groups. The informational and educational components provided by these three groups will also form a template for other groups.

Three qualifications for a new technique to be entered on the website are: (i) An independent and objective evaluation of the forecast performance that will normally take the form of a publication in a peer-reviewed journal; (ii) Consistency with the lead times, forecast periods, and spatial domains in Table 1; and (iii) demonstration of skill with appropriate verification measures. An announcement of opportunity to place additional techniques on the WMO website will be made when the prototype version of the website is established, and the policy guidance is complete. The National Meteorological and Hydrological Services will then be informed of the website availability, and a broader announcement to the tropical cyclone community will follow.

1. INTRODUCTION

A review of the progress on seasonal forecasts of tropical cyclone activity was presented at the Sixth International Workshop on Tropical Cyclones (IWTC-VI). This review documented a considerable number of agencies and research groups who were issuing seasonal forecasts. The recommendation of the ITWC-VI was that "all seasonal predictions of tropical cyclone activity should be validated in a manner appropriate to their form of output and reported on a central website hosted by WMO." Additional recommendations suggested a group of experts develop a common set of metrics for evaluating the skill of seasonal forecasts and document the purposes, goals, and uncertainties in these forecasts. The objective of this expert meeting is to carry out these recommendations from the IWTC-VI.

Camargo et al. (2007) summarized the review at IWTC-VI in a *WMO Bulletin* article. They focused on eight statistical and three dynamical types of seasonal forecasts and gave the websites where the forecasts were available. Except for the European Centre for Medium-range Weather Forecasts (ECMWF) website that is password-protected and available only to the National Meteorological and Hydrological Services (NMHSs), these websites are publicly available. At least in the USA, these seasonal forecasts are widely publicized, and considerable discussion of their skill has followed the active Atlantic seasons of 2004-2005 and less active Atlantic seasons of 2006-2007. Some National Hurricane Centre forecasters have expressed concern that negative publicity about seasonal forecast skill degrades public confidence in their forecasts and warnings. Discussion of seasonal forecast skill on the private Tropical Storms bulletin board subscribed to by many tropical cyclone forecasters and researchers highlighted the uncertainty and the improper interpretations by the public. Thus, one objective of the WMO website is to provide information on the goals and uncertainties of these seasonal forecasts.

As the numbers of seasonal forecasts increase, it is possible that great variability might exist among the forecasts. Thus, the development and application of a common set of metrics for evaluating the skill of seasonal forecasts is an important objective.

The purposes of the WMO website for seasonal tropical cyclone forecasts are:

(a) Provide a central website where consistent information on seasonal tropical cyclone forecasts and access to the operational forecasts (including the ECMWF) may be obtained by NHMSs;

(b) Provide consistent information about seasonal tropical cyclone skill and accuracy for all of the participating forecasts;

(c) Provide educational and background information for each participating tropical cyclone forecast method;

(d) Provide a central website for the benefit of tropical cyclone researchers working with or interested in seasonal forecasts;

(e) Provide a website with consistent information on seasonal tropical cyclone forecasts that is suitable for media and public access; and

(f) Provide an e-mail alert system to the NMHSs and tropical cyclone researchers (e.g., IWTC-VI address list and Tropical Storms bulletin board) when a new seasonal forecast becomes available on the website.

2. ORGANIZATION OF THE MEETING

This expert meeting was organized by the Tropical Meteorology Research programme under the Commission on Atmospheric Science (CAS)/World Weather Research Programme (WWRP). The National Centre for Atmospheric Research in Boulder, Colorado kindly hosted the expert meeting, which was held on 24-25 April 2008. The participant list is given in Annex A, and the agenda is in Annex B. As indicated by the title of the meeting, a key requirement for qualification to place a seasonal forecast on the WMO website is that the technique has skill. Thus, Ms Barbara Brown, who is the leader of the CAS/WWRP Verification Working Group, was an important participant in the expert meeting.

3. CONTENT OF TROPICAL CYCLONE SEASONAL FORECAST WEBSITE

Camargo et al. (2007, Table I) provided a summary of groups who issue seasonal tropical cyclone forecasts, regions for which the forecasts are issued, and websites where the individual forecasts are available. The two basic types of forecasts utilize statistical and dynamical models and the experts at the meeting represented groups preparing both types of forecasts.

Camargo et al. (2007, Table II) listed the outputs of the various seasonal tropical cyclone forecasts. The only common output of all statistical and dynamical techniques is the number of named tropical cyclones during the season, which will be referred to as a Level I variable in the following sections. However, the definition of “season” varies because some groups restrict the period to only the peak portion of the season. In addition, the lead time between the date the forecast is issued and the beginning of the forecast period varies. Some groups issue forecasts as early as December for the following Northern Hemisphere season and then issue updates as the season approaches. In some cases, the subsequent forecasts are revisions of the seasonal total based on new information, and the forecast for the number of total tropical cyclones in the later period is the revised seasonal forecast minus the number of tropical cyclones that have already occurred. Some groups issue monthly updates, even up to the month prior to the peak in tropical cyclone activity. Thus, one of the first objectives was to establish a common lead time and a common forecast period for the seasonal forecasts to be placed on the WMO website.

For each basin the approximate lead times (generally within 2-3 weeks) and the periods of the seasonal forecasts agreed for the WMO website are listed in Table 1. The first tier of participating groups who will work with the WMO webmaster to establish the displays and procedures is also listed in Table 1.

Table 1. **Approximate lead time and period of seasonal tropical cyclone forecasts in various basins to be placed on the WMO website. In developing the prototype website, a first tier of participants is provided in the last column (CSU: Colorado State University; NOAA: Climate Prediction Centre; IRI: International Research Institute; ECMWF: European Centre for Medium-range Weather Forecasts; CityU: City University of Hong Kong).**

BASIN	LEAD TIME	FORECAST PERIOD	FIRST TIER PARTICIPANTS
Atlantic	December June August	Entire season July – November August-November	CSU CSU, NOAA, IRI, ECMWF CSU, NOAA, IRI, ECMWF
Eastern Pacific	March May	June – November June – November	IRI, ECMWF NOAA, IRI, ECMWF
Western Pacific	April June November	July – November July – November January -- December	City U, IRI, ECMWF City U, IRI, ECMWF ECMWF
Australia	September November	November – March November – March	IRI, ECMWF IRI, ECMWF
Southwest Pacific	September November	November – March November – March	IRI, ECMWF IRI, ECMWF

It is emphasized that the forecast periods are a compromise among the various groups, some of whom must now adjust to these common periods. For example, the IRI must explore whether their technique can be extended to a longer period. Note that the IRI standard forecast period and updates at monthly intervals will continue to be available on their website (see Table 1 from Camargo et al. 2007). The ECMWF has previously issued seven month forecasts and now must extract numbers of tropical cyclones within the agreed forecast periods. The ECMWF produces a calendar year forecast for the number of tropical cyclones over the western North Pacific based on 13-month integrations of their seasonal forecast ensemble. The Tropical Storm Risk group also prepares a global forecast, but they are not in the first tier of participants. Note that the ECMWF forecasts are on a password-protected website that is available only to the Member countries, to the National Meteorological and Hydrological Services (NMHSs), and to selected researchers upon request. This same requirement for password-protection will also apply for the adjusted ECMWF forecasts mentioned in Table 1.

To evaluate and compare the skill of seasonal tropical cyclone forecasts within a basin, it will be necessary for all basin forecasts to cover the same spatial domain. Presently, the various statistical and dynamical models listed in Camargo et al (2007, Table I) do not have identical domains. Thus, each forecast that is to be on the WMO website is expected to adhere to the definitions of the WMO tropical cyclone regions (with some combinations) as indicated in Fig. 1. Notice in Camargo et al. (2007, Table I), and for the basins listed in Table 1 above, that none of these seasonal forecast techniques have been found to have skill in the Indian Ocean. When a skillful technique is developed for the North Indian or South Indian Ocean domains indicated in Fig. 1, it will be added to the WMO website.

Figure 1. **Domains for seasonal tropical cyclone forecasts that will be entered on the WMO website. These are basically the same domains as the WMO tropical cyclone regions with some combinations.**

Just as modifications must be made by some groups to match the agreed lead times and forecast periods in Table 1, several groups will have to adjust to the spatial domains in Fig. 1. Common practices need to be adopted for tropical cyclones that form in one basin in Fig. 1 and then move into another basin. That is, the formation will be counted in one basin, but the calculation of other tropical cyclone characteristics such as the Accumulated Cyclone Energy (ACE) index may be partially attributed to the other basin. This spatial adjustment task will involve re-counting the tropical cyclone-like vortices over the 25-year period of the ECMWF ensemble within the domains in Fig. 1 and developing a post-processing technique for adjusting the medians of the distributions. Considerable work will also be required to modify the IRI dynamical forecasts to fit into the agreed temporal and spatial domains, as well as to begin issuing the forecasts in the common format (number with a range).

A second forecast variable of the seasonal tropical cyclone activity provided by many of the groups is the ACE index, which is the sum of the six-hourly values of the square of the maximum wind speed. Note that in most basins this is the maximum 10-minute average surface sustained wind, but that in the Atlantic and eastern and central North Pacific a one-minute average is used to define the intensity. Because the ACE reflects both the duration and the intensity of all tropical cyclones in the season, it contains much more information about the potential damage that may occur during the season. In addition, some forecast techniques have more skill in predicting an integrated measure of tropical cyclone activity than in predicting the number of named storms.

Because of these desirable features of the ACE index, this variable will be considered as the Level II seasonal activity measure for the WMO website. Those groups in the first tier listed in Table 1 who are already predicting the ACE will work with the WMO webmaster to establish the displays and procedures for entering the ACE predictions on the website. The other groups are

encouraged to develop ACE forecasts for their areas of interest and add these forecasts to the WMO website on the time scale of 1-2 years as they are able. For example, the City University of Hong Kong has not provided ACE forecasts for the western North Pacific and will have to develop this capability. The IRI has provided ACE forecasts in the form of probabilities for the Northern Hemisphere basins but not for the Southern Hemisphere basins. One of the reasons for not forecasting ACE in the Southern Hemisphere region is the data quality in the region before 1980. Therefore, analysis needs to be done to examine if it will be possible to develop ACE forecasts for the Southern Hemisphere given these data quality issues. Although not indicated in Camargo et al. (2007, Table II), the ECMWF is now also forecasting ACE, albeit not for the same forecast periods listed in Table 1 above.

As summarized in Camargo et al. (2007, Table II), various groups forecast different indices of seasonal tropical cyclone activity. Since forecasts of the numbers of hurricanes/typhoons and the numbers of major hurricanes (Saffir-Simpson Categories 3, 4, and 5) are considered to be useful, and it appears that the statistical techniques may have some skill, these two variables will be considered as the Level III forecasts on the WMO website. Inclusion of these Level III forecasts is considered to be voluntary, and forecasts for other variables will be considered for inclusion in Level III after demonstration of skill.

Another requirement for inclusion on the WMO website is that the forecast group must provide a measure of uncertainty for any seasonal tropical cyclone forecast variable. Although the public or commercial groups such as the insurance companies desire an exact number of named storms or hurricanes, inclusion of an uncertainty measure will more properly inform the public regarding the nature of the forecasts. Some of this uncertainty is simply related to the limited predictability of the tropical cyclone variable on seasonal time scales. In addition, each technique has inherent limitations (e.g., accuracy of database for statistical techniques; numerical and physical processes limitations for dynamical models). Moreover, the uncertainty will vary with the different forecast lead times. Thus, each forecast on the WMO website must specify a range within which the actual number is expected to lie. More discussion of this range will be given in the verification section below.

Whereas the CSU forecasts for the Atlantic are discrete numbers, the NOAA forecasts for the Atlantic and eastern North Pacific and the CityU forecast for the western North Pacific include an expected range (± N storms). The IRI must convert their forecasts from a probabilistic form within terciles (above, normal, below seasonal activity) to specify an expected value with a specified range.

4. VERIFICATION MEASURES

As indicated in the title of the expert meeting, an evaluation of the skill of the seasonal tropical cyclone forecasts is required. This requirement is made less complex by the decision to specify a value plus/minus a range, and to not include probabilistic forecasts for which the verification measures are quite different.

A distinction is made here between the *accuracy* of a forecast and the *skill* of the forecast. A forecast that the number of tropical cyclones is above some climatological normal can be useful information for the public, even if the actual number of storms is not precisely forecast. Thus, an agency or a group may choose to characterize the "season type" as above normal (or even much above normal) in their pre-season discussion for the media and the public. However, the definition of normal (or above normal) for a statistical type based on the past 50-plus years is not the definition of normal for a numerical model for which hindcasts are only available for say 20-30 years. Given this potential confusion when both statistical and dynamical techniques will be available on the WMO website, it was decided to leave any characterization of season type to individual group or agency websites.

By definition, an evaluation of *skill* requires a comparison against some agreed-on reference or standard forecast technique. Typically, this standard will be a naïve forecast such as climatology or persistence. The reference forecast to be utilized for the seasonal forecast techniques to be included on the WMO website is the running-mean over the previous five years of that forecast variable. By using the previous five-year mean, some account is taken of the interdecadal variability of activity while smoothing out the interannual variability. Thus, a seasonal forecast technique will not be considered to have skill unless it produces forecasts with more accuracy than a simple mean over the previous five years. For the forecast range values, the standard deviation of the 5-year running mean of hurricane counts over the last 30 years will be used to estimate appropriate climatological prediction intervals that will be used as the reference forecast range. Ideally, the forecast range values on average will be narrower than the climatological range values. It is important to note that it is not possible to evaluate a single forecast using this measure. Over the long run, skillful forecasts should have (on average) a range that is both narrower than the climatological range, and that more frequently includes the observed value.

Since the skill of all the forecast techniques presented on the website will be evaluated against this same reference forecast, forecasters will be able to compare the skill of the statistical and dynamical techniques. By examining the skill of the techniques over time, the forecaster can assess the relative forecast performance for specific scenarios of interannual (e.g., an El Niño or La Niña year) or longer-period variations. Of course, the statistical techniques and dynamical models are evolving from year-to-year. Consequently, the time period of real-time forecasts after a new statistical technique or a new dynamical model is introduced may be only a few years. Thus, each group is required to provide an assessment against this skill measure for the hindcast period for the statistical technique or the numerical model. Cautionary notes need to be added regarding lowered expectations of real-time forecast skill versus the skill calculated for hindcasts of statistical techniques. Evidently, the dynamical model forecasts may be more skillful than hindcast simulations due to better ocean data and better data assimilation.

Since both a mean (or median) value and a range about the mean are to be included for each seasonal tropical cyclone activity variable, both values need to be verified. A typical display will be a box plot in which the top and bottom of the box are $\pm$ 25% about the median and thus can be interpreted as an indicator of 50% probability of the value occurring in that range. Other indicators such as $\pm$ 35% or 70% probability may also be selected. These larger ranges may not be useful in a basin such as the western North Pacific in which the natural variability is relatively

small and so the forecast may seem to be more skillful, but not be very useful. That is, *sharpness*, which is related to the width of the range, is also a desirable aspect of forecast performance.

To be considered skillful, the forecast technique must be more accurate than the reference forecast based on the mean of the variables for the previous five years. While this skill measure may be simply a difference in numerical values in the case of numbers of named storms, some normalization by the standard deviation or some other measure of variability may be useful (e.g., for inter-comparisons among the basins).

Another measure of forecast performance is the *reliability* of the forecast range. That is, if a 50% or 70% range is specified, how frequently are the forecasts within that range? One can imagine that in some seasons dominated by an El Niño or by a La Niña (i.e., a strong climatic signal), the forecasts may have a higher degree of confidence (smaller range about the median) than for a neutral El Niño Southern Oscillation (ENSO) year. In combination with sharpness, reliability provides an overall picture of forecast performance.

In addition to the demonstration of skill using the verification tools to qualify for display on the WMO website, a verification of the skill for the season just completed will be supplied by each group for posting on the website. The observed number of tropical cyclones and their intensity evolutions as determined by the Regional Specialized Meteorological Centres (RSMCs) (or Tropical Cyclone Warning Centres in the case of Australia) for the basin will be the basis for the seasonal evaluation. This standard may need to be re-considered in the western North Pacific since many of the statistical and dynamical techniques were developed using the Joint Typhoon Warning Centre (JTWC) archived data. In addition to the differences arising from one-minute average winds (JTWC) versus 10-minute average winds (RSMC-Tokyo) in defining a tropical storm or typhoon, some differences may arise in the determination of whether a cyclone in the subtropics is really a tropical cyclone.

Ms Barbara Brown of NCAR has volunteered to investigate the applicability of various statistical measures that may be appropriate for evaluating seasonal tropical cyclone forecasts (see verification section in Camargo et al. 2007 for some possible measures). She will use the 1984-2006 CSU data base as a trial since it is one of the longest samples, and will then circulate her suggested verification measures to other members of the Working Group on Verification for their inputs. Ms Brown will utilize an open software statistical package called “R” that the Joint Working Group on Verification has used in a tutorial. Since the package is compatible with several computing systems, it is hoped that other researchers planning to submit a seasonal forecasting technique for the WMO website will also utilize this package.

A key issue for the verification analysis is the availability of adequate samples of reliable records of tropical cyclone activity. In some basins such as the eastern North Pacific, reliable numbers of tropical cyclones are only available during the meteorological satellite era. Reliable estimates of intensities required for the calculation of ACE are particularly dependent on satellite estimates in all basins except the Atlantic where aircraft reconnaissance *in situ* observations are regularly available. This problem is particularly acute in the Southern Hemisphere basins.

5. WEBSITE DESIGN AND FUNCTIONALITY

Various websites were examined, and Nanette Lomarda had prepared a prototype of the front page. Even though this website will include both basin (regional) and global seasonal tropical cyclone forecasts, a majority of those accessing the website will only be interested in the basin in which they live. Thus, a map illustrating the basins similar to Fig. 1 is desirable so that a link can easily be made to the appropriate basin.

Note that this WMO website is not intended to supplant or replace the individual websites of the various groups. Rather, the purpose is to produce a self-consistent set of seasonal tropical cyclone forecasts in terms of lead times and forecast intervals for ease of comparison. Thus, a link to each participant's own website will be provided for detailed discussion and for tropical cyclone activity variables that are not included on the WMO website. Similarly, links to published papers that provide more details will be provided where this is allowed by the publishers.

In general, the content of the website will be as compact as possible while displaying the seasonal forecasts as hyperlinks in an easily understood format. An archive access is essential and an informational/educational component (to be discussed below) will be included since this website is intended for NMHS forecasters. Rather than attempting to consider many details of the website design, which was not the expertise of the participants, the WMO webmaster will be asked to create the design with the desired functionality.

Considerable effort will be required to establish the website and post the first forecasts. However, updates of the forecasts or insertion of new forecasts for the next season should be accomplished with automated inputs. Given that the new information is placed on an ftp site in the proper format, the responsibility for monitoring that the correct information has been added to the website will be the responsibility of the agency or group supplying the information. This mode of operations assigns responsibility to each forecasting group to verify their forecasts at the end of the season, to update the statistics, and to produce performance graphs for their technique or modelling approach. Minimal monitoring by WMO personnel is expected to be required.

An appropriate disclaimer will appear on the first page that indicates that WMO is simple providing a service by collecting these forecasts, and that WMO is not legally responsible for any actions taken in response to these forecasts.

6. INFORMATIONAL AND EDUCATIONAL COMPONENT

Whereas a certain amount of information about each statistical technique or numerical model needs to be available on the WMO website, it is not intended that this information be a substitute for what is available on the individual/agency website. Thus, only a short description (on the order of one page) will be provided so that the different characteristics of statistical and dynamical techniques are clear. For the statistical techniques, the list of predictors for each forecast variable should be provided, and for the dynamical approaches the model characteristics and the post-processing of the model output should be explained. In each case, both the advantages and the limitations of the technique or model approach should be stated.

The website will also cover how seasonal tropical cyclone forecasts should be used. Common misconceptions by the public such as interpreting these forecasts as landfall forecasts, or that a forecast of low number of tropical cyclones for the season means that protective measures can be reduced, need to be addressed. Each of the groups and agencies preparing these forecasts has to deal with these misconceptions, and it will be useful guidance to the NMHS forecaster as they interpret these seasonal forecasts for their clients. A selection of Frequently Asked Questions (FAQs) from various agencies would be appropriate for the WMO website (given consent and proper acknowledgment).

Since verification techniques for seasonal forecast are different from those for daily operational forecasts, an educational section on verification would be appropriate for NMHS forecasters. For example, the distinction between accuracy or information content and skill as it applies to seasonal forecasts should be addressed. The advantages and disadvantages of the proposed verification methods should be highlighted.

7. PROCEDURAL CONSIDERATIONS

The procedure to establish the WMO website will begin with the two Atlantic statistical forecasts by CSU and NOAA CPC and with the western North Pacific statistical forecasts by CityU because these techniques have a longer history and require less adaptation (with the exception that Professor J. Chan will need to develop an ACE forecast) than other first-tier groups or agencies listed in Table 1. These groups will provide sample forecasts and verification information to the WMO webmaster to establish a prototype website. Data formats and forecast submission procedures and timelines that are worked out with these three groups will then be the standard for other groups.

Another task is to establish the required informational and educational components for the website. The required documentation of the system characteristics is expected to be accomplished quickly working with the three first-tier groups mentioned above. This template will then be provided to the other groups. The educational component does not need to be completed immediately because the website will not be open to the NMHSs and others for many months, although some selected forecasters will be invited to evaluate the prototype website.

Policy guidance for the inclusion of a seasonal forecast technique on the WMO website needs to be established prior to an official opening of the website beyond the first tier of participants. The most important qualifications are: (i) An independent and objective description and evaluation of the forecast performance of the technique that will normally take the form of a publication in a peer-reviewed journal or in a internal agency report that has been stringently reviewed; (ii) consistency with the lead times, forecast period, spatial domains in Table 1, etc.; and (iii) demonstration of skill in terms of an adequate sample of forecasts with the appropriate verification statistics. Each of the first-tier of participants in Table 1 have met these considerations, although perhaps for slightly different forecast periods and/or spatial domains.

When the prototype version of the website is established and the policy guidance is complete, the WMO website will begin to be opened to other research groups or agencies. This

opportunity to place another technique on the website will be announced directly with the other groups in Table I of Camargo et al. (2007). Another direct announcement of the website availability will be made to the NMHSs via an e-mail list, so that the forecasters become aware of its existence and have a pathway to respond if they have suggestions and comments. Recall that these NMHSs will have full access to the password-protected ECMWF forecasts. A broader announcement on the Tropical Storms bulletin board will then follow to alert the tropical cyclone community to this new resource.

8. TASKS AND TIMELINES

A number of tasks need to be accomplished to generate the prototype WMO website for seasonal tropical cyclone forecasts. These tasks, approximate timelines, and responsible individuals are summarized in Table 2. Only approximate timelines can be given as these tasks have to be accomplished in addition to the scientists' normal duties. If these aggressive timelines are able to be met, the first bare-bones version of the website would be available for the August 2008 update for the first-tier statistical techniques in the Atlantic and western North Pacific for the Levels I and II variables. The next major upgrade would be the inclusion by April 2009 of the ECMWF forecasts (password-protected) and IRI forecasts for the Northern Hemisphere. The ECMWF and IRI forecasts for the Southern Hemisphere would be available for the September 2009 lead time.

Assuming that the first-tier statistical technique implementation is accomplished, and with the completion of the policy statement in Task 5, the announcement of opportunity to include new Northern Hemisphere techniques is anticipated at the beginning of 2009 so that forecasts from the additional techniques might be included for the June 2009 or August 2009 lead times. Assuming the first-tier Southern Hemisphere implementation is successful for the 2009-2010 season, announcement of opportunity for submission of new Southern Hemisphere techniques would be made in May 2010.

Table 2. Tasks required with suggested timelines for developing prototype seasonal tropical cyclone forecasts on the WMO website. People to be involved in each task are listed.

Task 1	Circulation of first draft report of expert meeting (5-10-2008); Response from participants (5-31-2008); preparation of final draft (6-15-2008) **People:** R. Elsberry (lead); S. Camargo (co-lead); All participants respond to draft.
Task 2	Initial consultations between WMO webmaster and three statistical technique group leaders facilitated by N. Lomarda (6-15-2008); Three statistical technique group leaders provide their June 2008 seasonal forecasts, their verification forecast statistics, their draft technique description, and their links to WMO webmaster (7-5-2008); Three statistical technique group leaders transmit their August update forecast to WMO in agreed format (8-3-2008); Initial prototype website containing the three Level 1 (number of named storms) August forecast updates for remainder of Atlantic and western North Pacific seasons becomes available (8-5-2008). **People:** G. Bell; J. Chan; P. Klotzbach; N. Lomarda; WMO webmaster
Task 3	Establish verification procedures: P. Klotzbach provides B. Brown with 1984-2006 data base of CSU seasonal forecasts for the Atlantic (5-5-2008);

	B. Brown applies selected verification measures to CSU seasonal forecasts and coordinates with Working Group on Verification as to appropriate measures (6-15-2008); B. Brown provides suggestions for seasonal tropical cyclone forecast verification measures, a description for inclusion on the WMO website including suggested figures (7-15-2008); Three statistical technique group leaders provide verification statistics and suggested figures for their techniques for inclusion on the WMO website (8-15-2008). **People:** B. Brown, G. Holland, and list as in Task 2
Task 4	Generate educational materials on seasonal forecasts and their proper utilization, FAQs, and interpretation of the verification (8-31-2008). **People:** G. Bell (lead); P. Klotzbach, J. Chan, F. Vitart
Task 5	Generate policy statement for qualification to enter a new technique on the website, including required documentation and verification (10-31-2008). **People:** S. Camargo (lead); all participants respond to draft
Task 6	Modification of ECMWF forecast technique for consistency in temporal periods (4-30-2009) **People:** F. Vitart
Task 7	Modification of IRI forecasts in Northern Hemisphere to convert to value ± range (4-30-2009) and in Southern Hemisphere (possibly including ACE depending on data quality issues)(8-31-2009). **People:** S. Camargo

ANNEX A

EXPERT MEETING to EVALUATE SKILL of TROPICAL CYCLONE SEASONAL FORECASTS

(Boulder, Colorado, USA, 24 – 25 April 2008)

LIST OF PARTICIPANTS

EXPERT TEAM MEMBERS

Dr Suzana Camargo (Chair)
Lamont-Doherty Earth Observatory
Columbia University
Palisades, NY 10964-8000
USA
suzana@ldeo.columbia.edu

Dr Gerry Bell
Climate Prediction Centre
NOAA Science Centre
5200 Auth Road
Camp Springs, MD 20746
USA
gerry.bell@noaa.gov

Prof. Johnny Chan
Laboratory for Atmospheric Research
City University of Hong Kong
Kowloon, Hong Kong
Johnny.chan@cityu.edu.hk

Dr Phil Klotzbach
Department of Atmospheric Science
Colorado State University
Ft. Collins, CO 80523
USA
philk@atmos.colostate.edu

Dr Frederic Vitart
ECMWF
Shinfield Park
Reading, RG29Ax
United Kingdom
Frederic.Vitart@ecmwf.int

INVITED EXPERTS

Ms Barbara Brown
NCAR
P. O. Box 3000
Boulder, CO 80303
USA
bgb@rap.ucar.edu

Dr Greg Holland
NCAR
P. O. Box 3000
Boulder, CO 80303
USA
gholland@ucar.edu

WMO

Chair, Tropical Cyclone Panel
Prof. Russell Elsberry
Department of Meteorology
Naval Postgraduate School
Monterey, CA 93943-5117
USA
Elsberry@nps.edu

Secretariat

Mrs Nanette Lomarda
Senior Scientific Officer
WWR/ARE/RES Dept
WMO
7 bis avenue de la Paix
CH 1211 Geneva
Switzerland
NLomarda@wmo.int

ANNEX B

EXPERT MEETING to EVALUATE SKILL of TROPICAL CYCLONE SEASONAL FORECASTS

(Boulder, Colorado, USA, 24 – 25 April 2008)

AGENDA

Thursday, 24 April 2008

0830 **Welcome and local facility information** *[Barbara Brown]*
WMO representative *[Nanette Lomarda]*

0845 **Introductions**
(Each participant will introduce themselves, and indicate their interest in the expert meeting and what they hope it will achieve)

0900 **Organization of workshop** *[Russ Elsberry]*
(Main issues to be resolved; desired outcome)

0915 **Purposes of the Seasonal Tropical Cyclone Forecast Website**
A review of the progress on seasonal forecasts of tropical cyclone activity was presented at the Sixth International Workshop on Tropical Cyclones (IWTC-VI). This review documented a considerable number of agencies and research groups who were issuing seasonal forecasts. The recommendation of the ITWC-VI was that "all seasonal predictions of tropical cyclone activity should be validated in a manner appropriate to their form of output and reported on a central website hosted by WMO." Additional recommendations suggested a group of experts develop a common set of metrics for evaluating the skill of seasonal forecasts and document the purposes, goals, and uncertainties in these forecasts. The objective of this expert meeting is to carry out these recommendations from the IWTC-VI.

Camargo et al. (2007) summarized the review at IWTC-VI in a *WMO Bulletin* article. They focused on eight statistical and three dynamical types of seasonal forecasts, and gave the websites where the forecasts were available. Except for the European Centre for Medium-range Weather Forecasts (ECMWF) website that is password-protected and available only to the National Meteorological and Hydrological Services (NMHSs), these websites are publicly available. At least in the USA, these seasonal forecasts are widely publicized, and considerable discussion of their accuracy has followed the active Atlantic seasons of 2004-2005 and less active 2006 and 2007 seasons. Some National Hurricane Centre forecasters have expressed concern that negative publicity about seasonal forecast accuracy degrades public confidence in their forecast and warnings. Discussion of seasonal forecast accuracy on the Tropical Storms bulletin board highlighted the uncertainty and the

improper interpretations by the public. Thus, one objective of the WMO website is to provide information on the goals and uncertainties of seasonal forecast.

As the numbers of seasonal forecasts have increased, the likelihood of greater variability among the forecasts is increased. Thus, the development and application of a common set of metrics for evaluating the skill of seasonal forecasts is an important objective.
Thus, the purposes of the WMO website for seasonal tropical cyclone forecasts are:

(1) Provide a central website where information on seasonal tropical cyclone forecasting and access to the operational [*Discussion of definition required*] forecasts (including the ECMWF) may be obtained by NHMSs;
(2) Provide a central website for benefit of tropical cyclone researchers working with or interested in seasonal forecasts;
(3) [*Discussion topic*] Provide a website suitable for media and public access; and
(4) Establish an e-mail alert system for the NHMS, and tropical cyclone researchers (e.g., IWTC-VI address list and Tropical Storms bulletin board) indicating when new seasonal forecast information becomes available on the website.

1000 *Break*

1015 **Content of website** *[Suzana Camargo and Johnny Chan]*

Based on the pre-workshop survey, some difference of opinion exists as to the content of the website. In one opinion, the WMO website should primarily be a central repository in which agencies/researchers may post information in free-form with a minimum of restrictions. Another opinion is that the WMO website should be more controlled, have more uniformity, and generally be more restricted. Thus, the issue of content is to what extent the website should be more inclusive to encourage (and make it easier for) more seasonal forecast groups to participate versus being more exclusive to maintain standards and uniformity.

Discussion questions (preliminary):

What will and what will not be on the website (see list in Camargo et al. 2007)?
What are the qualifications for inclusion?
Will linkages be given to other websites that are not considered to be qualified?
Will a separate section be included for non-operational or experimental techniques?
What degree of uniformity/consistency should be enforced?
What “political” considerations (e.g., Taiwan or other non-WMO member)?
What tropical cyclone seasonal forecast variables?
Should all forecasts be required to have an uncertainty or skill measure?
Should we anticipate (and/or facilitate) that a user will want a consensus forecast by some combination?

1215 *Lunch*

1315 **Verification of forecast requirements** *[Barbara Brown and Greg Holland]*

Depending on the results of the above discussion of the content to be included on the

WMO website, the IWTC-VI recommendation was that an appropriate set of metrics be established for documenting the skill of the seasonal forecast.

Discussion questions (preliminary):

Forecasts are issued in various formats: deterministic, probabilistic, certain range of values. Each of these types of forecasts has different verification measure that is more appropriate for each type. Will the forecasts continue to be issued on a diverse manner or will we have an determined format?

According to the format of the forecasts (deterministic or probabilistic, for instance), different verification measures will be more appropriate. How will that be conveyed in the website?

For statistical forecasts, what cross-validation procedure is adequate verification if a large number of predictors were included in the development sample?

For dynamical forecasts, how many years are going to be required to analyze the hindcast skill of the model, 30, 50?

In the case of probabilistic forecasts, are terciles the best approach? Or rather than mention terciles, just state that 10 or less,11-15, and 16 or more (for Atlantic).

If alternate is value plus an uncertainty range (e.g., 10 $\pm$ 2), then what is the associated confidence level that is not too high (interval is so large that includes too broad of a range) and not too low (so that too many seasonal totals fall outside of the forecast range and thus the forecasts are perceived to not be accurate)? How will be the uncertainty range be defined uniformly across the models?

1515 *Break*

1530 **Website design and functionality** *[Phil Klotzbach and Nanette Lomarda]*

All who responded to the pre-meeting survey agreed that a separate password-protected website for the NMHSs was required to assure that the ECMWF (and hopefully the EUROSIP) could be included. It is anticipated that a prototype design might be presented to get further inputs. The functionality will depend on decisions made earlier in the meeting.

Discussion questions (preliminary):

Should consideration be given to becoming a link to another established seasonal forecast website versus a dedicated WMO/CAS/TMR website?

What is the essential functionality of the website?

Friday, 25 April 2008

0830 **Procedural considerations** *[Gerry Bell and Frederic Vitart]*

Clearly, some considerable effort is going to be required to establish the WMO website, but then less effort should be required to maintain/update the website once the procedures are in place. More effort will be required if a more structured, more uniform presentation is desired than if it is free-form in terms of inputs. An important outcome of this meeting is to establish the policies and procedures that will guide participation in the website.

Discussion questions (preliminary):

How and who will contact the various seasonal tropical cyclone forecast groups to enlist their participation?

What will be the time schedules for submission of the inputs by the groups, including:

(i) First seasonal forecasts; (ii) Information about the technique; and (iii) Annual or more frequent updates?

What procedures and agreements are needed to establish the password-protected website? Who is responsible for enforcement when violations occur?

Who will review the information about the technique provided by the various agencies/groups to ensure that it meets the policy guidelines?

Who will prepare the initial educational materials regarding the goals, proper uses for, and limitations of seasonal forecasts of tropical cyclone activity?

Who will establish the alert system procedures and build the e-mail list for the alert system?

1000 *Break*

1015 **Informational/Educational component** *[Suzana Camargo]*

If it is agreed that the WMO website should have an educational aspect about seasonal forecast approaches, techniques, and limitations, then the level of the explanations should be appropriate for NMHS forecasters and [what?] other groups.

Discussion questions (preliminary):

Should there be a generic description of statistical and dynamical techniques, or should each activity/group provide detailed descriptions of their technique (with references)?

Should there be a general discussion on the skill and uncertainties of the forecasts?

Should a section on Frequently Asked Questions (FAQ) be included (perhaps borrowed from Chris Landsea's site)? e.g., What is ENSO? Why is ENSO so important for seasonal tropical cyclone forecasting? What is the ENSO predictability barrier for seasonal forecasts?, etc.

1130 ***Wrap-up*** *[Russ Elsberry]*

(Further steps, writing assignments)

World Weather Research Programme (WWRP)

Report Series

Sixth WMO International Workshop on Tropical Cyclones (IWTC-VI), San Jose, Costa Rica, 21-30 November 2006 (WMO TD No. 1383**) (WWRP 2007 - 1).**

Third WMO International Verification Workshop Emphasizing Training Aspects, ECMWF, Reading, UK, 29 January - 2 February 2007) (WMO TD No. 1391) **(WWRP 2007 - 2).**

WMO International Training Workshop on Tropical Cyclone Disaster Reduction, Guangzhou, China, 26 - 31 March 2007 (WMO TD No. 1392) **(WWRP 2007 - 3)**.

Report of the WMO/CAS Working Group on Tropical Meteorology Research, Guangzhou, China, 22-24 March 2007 (WMO TD No. 1393) **(WWRP 2007 - 4).**

Report of the First Session of the Joint Scientific Committee (JSC) for the World Weather Research Programme (WWRP), Geneva, Switzerland, 23-25 April 2007 (WMO TD No. 1412) **(WWRP 2007 – 5).**

Report of the CAS Working Group on Tropical Meteorology Research, Shenzhen, China, 12 - 16 December 2005 (WMO TD No. 1414) **(WWRP 2007 – 6).**

Abstracts of Papers for the Fourth WMO International Workshop on Monsoons (IWM-IV), Beijing, China, 20 - 25 October 2008 (WMO TD No. 1446) **(WWRP 2008 – 1).**

Proceedings of the Fourth WMO International Workshop on Monsoons (IWM-IV), Beijing, China, 20 - 25 October 2008 (WMO TD No. 1447) **(WWRP 2008 – 2).**

WMO Training Workshop on Operational Monsoon Research and Forecast Issues – Lecture Notes, Beijing, China, 24 – 25 October 2008 (WMO TD No. 1453) **(WWRP 2008 – 3).**