TCC's Research and Development Activity
- Development of a downscaled probabilistic one-month forecasts suitable for the use in socio-economic sectors in Southeast Asia -

1. Purpose of this research

Tokyo Climate Center (TCC), Japan Meteorological Agency (JMA), has the mission of assisting National Meteorological and Hydrological Services (NMHSs) in the Asia-Pacific region in advancing climate services for preventing and mitigating climate-related disasters. In 2004, TCC started conducting a three-year research project, in cooperation with the FUJITSU FIP Corporation, on the development of detailed probabilistic one-month forecasts in Southeast Asia which are expected to be incorporated into decision-making processes in a variety of socio-economic sectors. The main three objectives of this research project are as follows:

1) development of the technique deriving appropriate probabilistic forecasts from JMA's one-month Ensemble Prediction System (EPS) products,
2) development of the statistical downscaling technique for observation-point forecasts in Southeast Asia from global prediction model outputs, and
3) research on effective ways to use detailed probabilistic forecast based on the techniques developed in the above 1) and 2) in socio-economic activities.

2. Achievements in 2004

(1) Method

The objective of the research in 2004 was to determine the best method out of five candidates for deriving proper probabilistic forecasts of temperature and precipitation from EPS outputs through verifying both the grid point probabilistic forecasts and the point-wise probabilistic forecasts at some specific observatories in Southeast Asia and in Japan downscaled from the EPS GPVs (Grid Point Values).

At that point in time, thorough hindcast experiment had not been accomplished. Therefore, the operationally archived one-month EPS GPVs from March 2001 to February 2004 were used for verification. Total number of the verified forecast was 156, each has 26 ensemble members. Model climatology was calculated with the 10-year (1984-1993) hindcast from the end of each month (5 members each). Five candidates to be examined were 1) No Calibration, 2) Bias Correction (only the systematic bias was calibrated), 3) Gaussian Distribution (estimating Gaussian error distribution by the linear regression between the ensemble mean forecast and the observation), 4) Gauss Kernel 1 (estimating Gaussian error distribution of each member forecast by the least-squares cross-validation method (Silverman, 1986) and then averaging them), 5) Gauss Kernel 2 (same as the Gauss Kernel 1 except for using the linear regression method).

The grid point forecasts on the 2.5 degree mesh over the whole globe were verified against the NCEP/NCAR reanalysis for 2-meter temperature and the GPCP-1DD for precipitation. Both 28-day mean and the weekly means, 2-8days and 9-15days, were verified. A simple linear interpolation method was applied for the point-wise forecasts, and verified against the daily observation collected by the APN (Asia-Pacific Network for Global Change Research).

(2) Major results

i. Bier Skill Score (BSS), reliability and resolution were examined for each season. It was found that the Gaussian Distribution method generally showed the best skill among the five candidates, and the second best one was the Gauss Kernel 2.

ii. It was shown that JMA's operational one-month EPS is able to produce meaningful probabilistic forecasts of 28-day mean and the second week (9-15day) mean temperature anomaly even at large deviations from normal, if adequately calibrated (Figure 1).

iii. It was shown that JMA's operational one-month EPS is able to produce meaningful probabilistic forecasts of 28-day mean and the second week (9-15day) mean precipitation anomaly in binary categories (above or below normal), if adequately calibrated. However, the skill scores were much smaller than those of temperature.

iv. The point-wise probabilistic forecasts also showed similar results as the grid-point forecasts described at ii and iii. However, the skill score varied from point to point, especially for precipitation forecast.

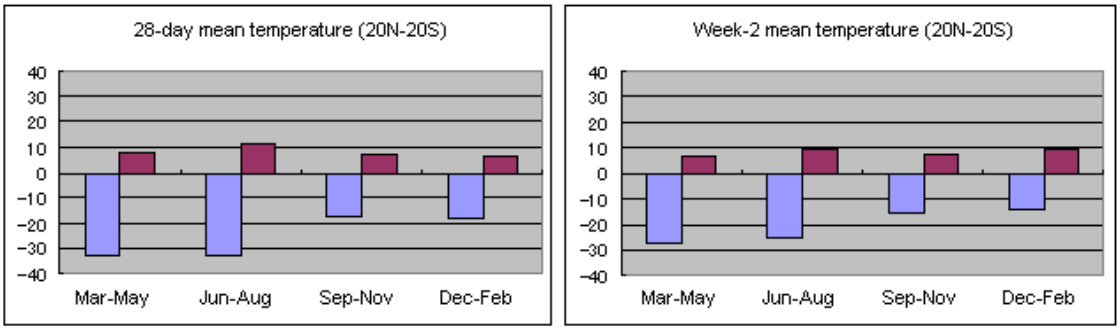

Figure 1 Brier Skill Scores of surface temperature regarding the probability of the deviation from the average larger than its standard deviation

Left and right panels indicate 28-day and the second week mean temperature forecasts averaged in the tropics between 20 N to 20 S, respectively. Vertical axis is Brier Skill Score multiplied by 100. Positive Brier Skill Scores indicate more skillful forecast than climatological forecast. Blue and red bars show Bias Correlation Model and Gauss Model, respectively.

(3) Recommendation for further research

This research suggested that it is possible to derive meaningful probabilistic forecasts statistically from JMA's one-month EPS outputs, if properly calibrated. However, there remained some issues to be examined in the future. They are:

1) to use long-term hindcasts, at least more than 20 years, in order to derive statistically more reliable results;

2) to improve the statistical downscaling technique, especially for precipitation forecasts, by considering orographical effect, that is the lower-level wind speed which blows upward and downward along mountain slopes; and

3) to construct a longer-term and higher-quality surface climate database which data are essential for deriving point-wise probabilistic forecasts suitable for socio-economic applications.

3. Achievements in 2005

In the second year of this project, 2005, three research objectives were set in accordance with the first year's recommendations. They are:

1) to construct a longer-term and higher-quality surface climate database in the Southeast Asia region;
2) to improve the statistical downscaling technique, especially for precipitation forecasts; and
3) to search the best use of the point-wise probabilistic forecasts and its applications through communication and cooperation with the producers and users of climate prediction information in the Southeast Asian countries.

(1) Construction of a surface climate database

Objectives and methods

The objective of this component is to derive a long-term and high-quality surface climate database of daily maximum/mean/minimum temperature and total precipitation as many as possible from five kinds of surface climate datasets. They are the data collected through the ASEAN, APN (Asia Pacific climate Network), GCOS GSN (Global Surface observation Network) and WCRP GAME (GEWEX Asian Monsoon Experiment) projects and the operational SYNOP data collected via the GTS and archived at JMA. After objective and subjective data quality checking for each dataset, they are combined into a single database, which is used for the improvement of the statistical downscaling technique.

Results

A longer-term and higher-quality surface climate database of daily maximum/mean/minimum temperature and daily precipitation compared with the existing climate dataset was successfully constructed for the Southeast Asia region. The number of the observatories, where we could estimate the daily normal, was over 200 for temperature and 300 for precipitation about three times as many as the existing one. These new daily surface climate data are quite useful not only for developing and verifying the point-wise probabilistic forecast, but also for monitoring and assessing the abnormal climate condition in Southeast Asia operationally at JMA on a daily basis.

(2) Improvement of the statistical downscaling technique

Objectives and methods

The final goal of this research is to examine the statistical relationship between GPVs (Grid Point Values) of numerical model outputs and surface observation data. However, the long-term hindcasts of the operational one-month EPS were not available at that time. So, instead of those, the JRA-25 (Japanese 25-year reanalysis) data were used. This corresponds to the perfect prognosis assumption. The main concern was placed on the effect of the orography on the downscaling of precipitation. To make better linear regression formula, each of several extra predictors, which used different resolution of orography, were added to the basic predictor, interpolated precipitation, and were examined whether it could improve the estimation of the observed precipitation. The daily precipitation database constructed at the above component (1) was used to obtain predictants. It enabled us to examine the seasonal and spatial patterns of the orographic effect.

Results

The statistical relationships were examined for the monthly mean precipitation at each month and observatory. It was found that the effect of the orographical predictor was quite different from place to place and season to season. Four classifications seemed possible: 1) where the JRA-25 precipitations reproduce the observed precipitation well without any calibrations, such as the eastern part of the Philippines in wintertime, 2) where the JRA-25 precipitations correlates with the observed precipitation well and the orographic effect is not so important, such as the western part of the Malay Peninsula in wintertime, 3) where the orographic predictor significantly improves the estimation, such as the western part of Thailand, and 4) where the orographic effect is not enough to reproduce the observed variability of precipitation, such as the inland area of Indochina Peninsula in summertime. Figure 2 shows some of the results. The relationships were examined for the weekly precipitation of each month, too, and almost the same results came out, though the orographical effect seemed a little smaller than the monthly cases. This research gave us valuable information on the characteristics of the JRA-25 precipitation in the tropics, too.

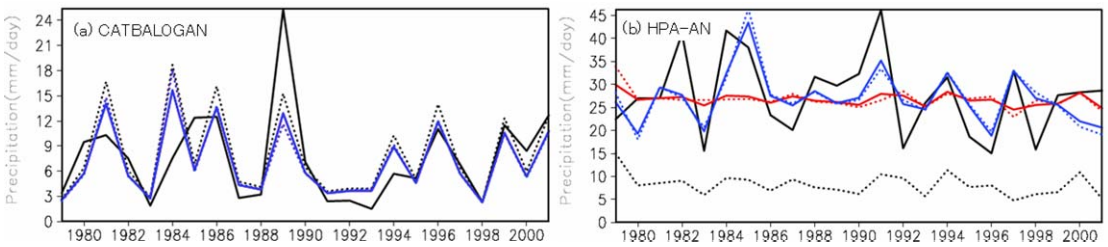

Figure 2 Time series of monthly mean precipitation (mm/day)
Left and right panels show Catbalogan, the Philippines, in January and Hpa-an, Myanmar, in June, respectively. In both panels, solid and dot black lines show precipitation of observation and of JRA-25, respectively. In left panel, blue line indicates the precipitation estimated from single regression on JRA-25 precipitation. In right panel, red and blue lines indicate the precipitation estimated from single regression on JRA-25 precipitation and from multiple one on JRA-25 precipitation and wind multiplied by the slop of terrain, respectively.

(3) Research on the possible field for climate forecast application

Objectives and methods

To develop tailored products, it is essential to identify the possible field to which the detailed climate forecasts are applied. In order to commence the cooperative research with NMHSs for making better use of the downscaled probabilistic one-month forecasts in socio-economic sectors in Southeast Asia, a TCC staff visited the TMD (Thai Meteorological Department) and the MMS (Malaysian Meteorological Service) and the users of their climate information.

Results

It was quite informative for us to visit and talk with the direct users of our products. We could understand the each other's current status of climate related services. TCC and both TMD and MMS agreed to promote the cooperative and collaborative relationships to develop advanced climate information applications. It was identified that agriculture is the top priority field for advancing climate application and the detailed and precise forecast of precipitation are primarily required. It was recognized that we would promote direct communication with the end-users of

our climate information.

(4) Recommendation for further research

The objectives of the second year's research were mostly achieved. However, there remained some issues, as below, to be further examined in the future.

1) Update and provision of the surface climate database

In order to keep the database up to date, we should continue to try to collect surface observation data operationally. The SYNOP report seems to serve the purpose, but we should develop more advanced data quality checking procedures to ensure the quality of the database. This database is thought to be the best for this region, so we should consider to make it available for the member NMHSs, after confirming the re-dissemination polices of each original dataset.

2) Improvement and enhancement of the statistical downscaling technique

This year, the PPM-type relationship was examined. However, considering the relatively low skill of precipitation forecast, we should develop the MOS-type downscaling technique by using the 20-year hindcasts of the JMA's operational one-month EPS, which is going to be completed in the first half of 2006. We might introduce some predictors representing the large scale circulation to improve the skill of the statistical downscaling technique.

3) Production and verification of probabilistic point forecasts

Our final goal is to provide point-wise probabilistic forecast in the Southeast Asia. The above 20-year hindcasts, which consist of 10 ensemble members from the end of each decad, will be used for developing and verifying the technique to produce probabilistic forecasts. In order to examine the practical utility of those prototype products, they will be provided to TMD and MMS for evaluation and development of tailored information for specific users. This kind of activity sould be extended to other NMHSs in the region in the future.

4. Plans on research in 2006

In the last year of this project, 2006, three research objectives were set in accordance with the second year's recommendations. They are:

1) to develop and evaluate the MOS-type statistical downscaling technique, especially for precipitation forecasts in the Southeast Asia region using the 20-year hindcast data;
2) to develop and evaluate the point-wise probabilistic forecast using the 20-year hindcast data; and
3) to provide the above prototype products to TMD and MMS for evaluation of their practical utility for the development of tailored information for specific users.