Section 6

Developments in global forecast models, case studies, predictability investigations, global ensemble, monthly and seasonal forecasting

Atlantic Tropical Cyclone Activity in EC-Earth Full Field Initialized Decadal Forecasts

Louis-Philippe Caron[1] Colin G. Jones[2] Francisco J. Doblas-Reyes[3]
[1] *Department of Meteorology, Stockholm University*
[2] *Rossby Center, Swedish Meteorological and Hydrological Institute*
[3] *Institut Català de Ciències del Clima*
emails: caron@misu.su.se, jones.colin@smhi.se, f.doblas-reyes@ic3.cat

Seasonal forecasts of tropical cyclone activity are routinely performed, with relative success, in various centers around the world (Zhao et al., 2010). However, predictions of Atlantic tropical cyclone statistics beyond a one-year horizon still remain elusive. At the decadal timescale, Atlantic TC activity is modulated by the Atlantic Multidecadal Oscillation (AMO), a fluctuation in Atlantic SSTs (Goldenberg et al., 2001). A recent study has found some level of predictability of the AMO at the multi-annual timescale (García-Serrano and Doblas-Reyes, 2012), thus suggesting potential predictability of Atlantic TCs over a similar timescale. Here, we describe the first steps in our attempt to move beyond the seasonal horizon towards making skillful multi-annual forecasts of Atlantic TC activity.

Using the CGCM EC-Earth, we performed a series of five-member ensemble re-forecasts, starting on November 1st, for every five years of the 1960-2005 period. Each forecast is run for a 10-year period. The atmosphere and land surface initialization was taken from the ERA-40 reanalysis for all start dates before 1989 and from ERA-Interim (Dee et al., 2011) afterwards. The ocean initial conditions have been taken from the 3D-Var five-member ensemble ocean re-analysis known as NEMOVAR-COMBINE (Balmaseda et al., 2010). EC-Earth is a coupled atmosphere-ocean model developed by a number of meteorological services and research groups in Europe. More information about EC-Earth can be found in Hazeleger et al. (2010).

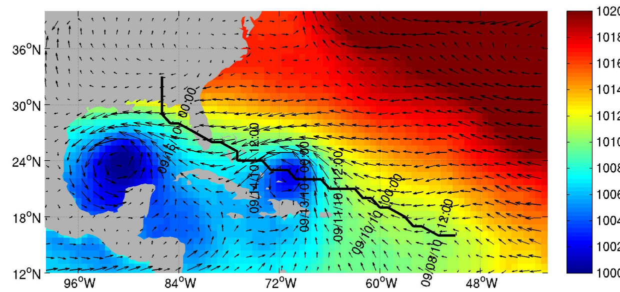

Figure 1: Mean sea level pressure in EC-Earth during a month of September. The arrows represent the surface wind. A tropical cyclone is seen in the Gulf of Mexico while another one is seen approaching the U.S.

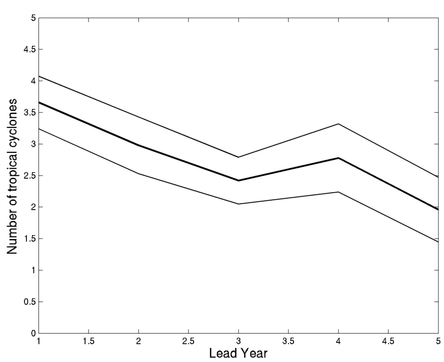

Figure 2: Downward trend in the number of tropical cyclones present in the first years of the forecasts. The thick black line represents the ensemble mean while the thin black lines represent 1 std. dev. above and below the ensemble mean.

The tracking of tropical cyclones in EC-Earth data is performed using a tracking algorithm developed during a previous series of studies (Caron and Jones, 2011; Caron et al., 2012) where it was shown to skillfully detect and track tropical cyclones present in model simulations. The detection criteria are based on Walsh et al. (2007) and include:

- a minimum in surface pressure (considered the center of the storm).
- strong surface (10 m) winds in the vicinity of the storm center.
- a warm core in the mid- to upper-troposphere.
- the number of consecutive, detected centers cover at least a 24 h period.

In EC-Earth hindcast integrations, tropical cyclones are seen forming over the Atlantic basin, including the area referred to as the Main Development Region (region limited by 8°N, 20°N, 80°W and 20°W; see figure 1). However, the mean annual number of storms (∼2-3) detected is well below the 1960-2010 climatological average (∼8). Given previous results obtained by other GCMs integrated at similar resolutions (Camargo et al., 2005), a low bias in the total storm count over the Atlantic is not unexpected. In this case however, the bias appears to be strengthened by a downward drift in tropical Atlantic SSTs. This appears to be supported by a significant downward trend in TC numbers as a function of lead year in the first five years of the hindcasts (figure 2). The low number of TCs in the simulations compared to observations makes it difficult to draw any conclusions regarding the ability of the hindcasts to capture TC activity.

This observed drift is inherent to decadal prediction using full field initialization. Standard procedures exist to correct for continuous fields such as temperature. However, this drift in SSTs has a particularly profound impact on simulated tropical cyclones since these storms require ocean temperature to be above a certain threshold (∼26°C) for their formation. Any drift in SSTs below that value will significantly reduce, if not completely shut down, TC formation. Figure 3 compares the climatological mean SSTs over the Atlantic for the August-October season between observation and the series of hindcasts. It is clear that EC-Earth SSTs have drifted below the required threshold over a significant portion of the basin, most likely hindering cyclogenesis.

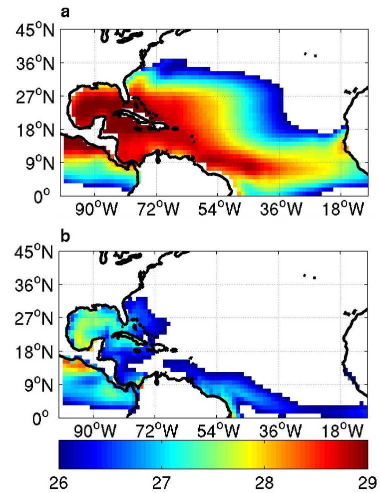

Figure 3: Mean a) observed and b) hindcasat simulated SSTs during the ASO season over the North Atlantic region.

There is no substitute to compensate for the absence of TCs caused by low model SSTs in EC-Earth hindcasts. However, it is possible that, if SSTs were to remain above the 26°C threshold required for TC formation, TC activity would rise sufficiently for comparison with observations to become feasible. It is worth mentioning that most of the model drift that we suspect is partly responsible for the low bias in TC numbers occurs during the first months of the hindcasts, which are all initialized on November 1st. The official start of the hurricane season is on August 1st. This suggests that i) the impact of the drift on TC formation is likely stronger than what is shown in figure 2, since most of the drift in SST has already occurred by the start of the first hurricane season and that ii) if no drift were present in the simulation, the mean number of tropical cyclones during a given season would be much closer to the observed climatological average.

We thus plan to re-run the atmosphere component of EC-Earth using the hindcast-derived SST anomalies superimposed onto observed climatological SSTs. In doing so, we will ensure that SSTs remain above the required threshold for TC formation while also retaining the SST anomalies derived from the individual hindcasts. Furthermore, because the computational cost of running EC-Earth is significantly reduced in this configuration, this will also allow us to increase the model resolution to ∼0.7°, which should further contribute to increasing cyclogenesis over the MDR. These results will be available in the upcoming months.

References:

Balmaseda, M.A., K. Mogensen, F. Moteni and A.T Weaver, *NEMOVAR Technical reports No. 1*, (2010).
Camargo, S. J., A. G. Barnston and S. E. Zebiak, *Tellus*, **57A**, 589-604 (2005).
Caron, L.-P., C. G. Jones, P. A. Vaillancourt and K. Winger, *Clim. Dyn.* (2012). doi: 10.1007/s00382-012-1311-6
Caron, L.-P. and C. G. Jones, *Clim. Dyn.* (2011). doi: 10.1007/s00382-011-1160-8
Dee, D. P. and co-authors, *Q.J.R. Meteorol. Soc.*, **137**, 553-597 (2011).
Goldenberg, S. B., C. W. Landsea, A. M. Mestas-Nuñez and W. M. Gray, *Science*, **293**, 474-479 (2001).
Hazeleger W. and co-authors, *Bull. Amer. Meteorol. Soc.*, **91**, 1357-1363 (2010).
García-Serrano, J. and F. J. Doblas-Reyes, *Clim. Dyn*., (2012). (under review)
Uppala, S. M., and co-authors, *Q. J. R. Meteorol. Soc.*, **131**, 2961-3012 (2005).
Walsh K. J. E., M. Fiorino, C. W. Landsea and K. L. McInnes, *J. Clim.*, **20**, 2307-2314 (2007).
Zhao, M., I. M. Held and G. A. Vecchi, *Mon. Wea. Rev.*, **138**, 3858-3868 (2010).

Flux correction and seasonal predictability

Michel Déqué and Lauriane Batté
Centre National de Recherches Météorologiques (CNRS/GAME), Météo-France.
42 avenue Coriolis F-31057 Toulouse Cédex 1, France, michel.deque@meteo.fr

Numerical models of the atmosphere and the ocean are approximations to the reality, and are thus not expected to fit exactly to it, even on long time averages. The difference between the multi-year average model variables and the corresponding observed values is named the systematic error. In numerical climate scenarios, this error is seldom shown (e.g. in IPCC reports) because modellers exhibit the difference between a future climate and a reference climate, both produced by the same model. The hidden assumption is that the systematic error change is smaller than the mean climate change. This difference is sometimes added to observed values in impact studies. This way of proceeding is named the delta method (Déqué, 2007a). In the earlier coupled scenarios, the systematic error in surface fluxes was so big that the ocean drifted toward an unrealistic climate. To avoid this, a constant empirical term was added to the coupling interface. This term was named flux correction (Cubasch et al., 1992). Progresses in developing and calibrating flux parameterizations have made this technique obsolete in recent coupled long integrations.

Systematic errors also exist in seasonal forecasting. Their amplitude may be larger than the predicted signal, in particular when ensemble means are considered. However, they do not appear in forecasts, as scientists produce a series of hindcasts to evaluate the model climatology and consider the anomaly, i.e. the difference between a model forecast and the hindcast climatology. This anomaly is compared with the difference between an observed variable and its climatology. However, this *a posteriori* correction does not prevent the model to badly simulate large-scale teleconnections which contribute to the predictability of the system. Guldberg et al. (2005) proposed to apply an *a priori* correction to the model to improve the seasonal predictability. The aim was not to prevent the ocean from drifting, but to maintain the atmosphere in a mean state close to the observed one. To this purpose, the error must be corrected at its source: a surface flux error can originate in a lack of cirrus clouds. The technique consisted in adding to the model equations, at each level and time step, a correction of the tendency error. This tendency error was calculated in a previous model simulation nudged toward a reanalysis. The long term average of the nudging term (the difference between model and reanalysis multiplied by the relaxation factor) was considered as the mean tendency error of the model. Subtracting this term in the model equations in a seasonal hindcast experiment did not lead to the expected improvement. The systematic error was weakly reduced and no impact on the forecast scores was observed.

The experiment we present here is an attempt to improve the above method. The systematic error is a statistical concept, because the model error is not systematic but changes according to the situation. Because the model is highly non-linear, applying every day the same correction is not the best way to proceed. The experiment is based on three hindcasts of the 1979-2010 period with a version of CNRM-CM5. (Arpege TL127 with 91 vertical levels, Nemo 1° with 42 vertical levels). The hindcasts start on November 1^{st}, and we focus on the DJF period.

- E1: a 32 NDJF hindcast with 4 members in which a weak nudging toward ERA interim above 850 hPa (10 days for vorticity, 30 days for temperature and moisture) is applied every 6 hours. The daily nudging terms are stored.
- E2: a 32 NDJF hindcast with 15 members in which the initial situations are perturbed (as in E1).
- E3: a 32 NDJF hindcast with 60 members in which every 6 hours a nudging term is randomly selected among the E1 saved terms (same calendar month leaving the current year). The correction is linearly interpolated in time between two consecutive 6h steps.

E2 is a control experiment, E3 is an experiment in which we attempt to correct the model by using the probability distribution of past errors. The terms saved in E1 help estimate the model error statistics in forecast mode. E1 is not an actual hindcast since it uses verification data: its forecast scores for seasonal means (not shown) are obviously very high.

Figure 1 shows that the mid-latitude bias is significantly reduced. Table 1 shows the anomaly correlations of the DJF period for a few parameters. In order to properly evaluate the improvement due to the correction technique, 15 members are randomly drawn out of the 60 members, and we show the score quantiles (based on 500 series) corresponding to 5%, 50% and 95%. When the score of E2 is below the 5% quantile of E3, we can consider the score improvement as significant. This is the case for most variables, except for NAO which is however generally improved. The bias and score improvements are mainly due to the mean term of the perturbation, as shown by later experiments at lower resolution. However the random part does not reduce this positive effect and increases the intraseasonal as well as the seasonal intra-ensemble variability which is a further improvement when evaluating probability prediction.

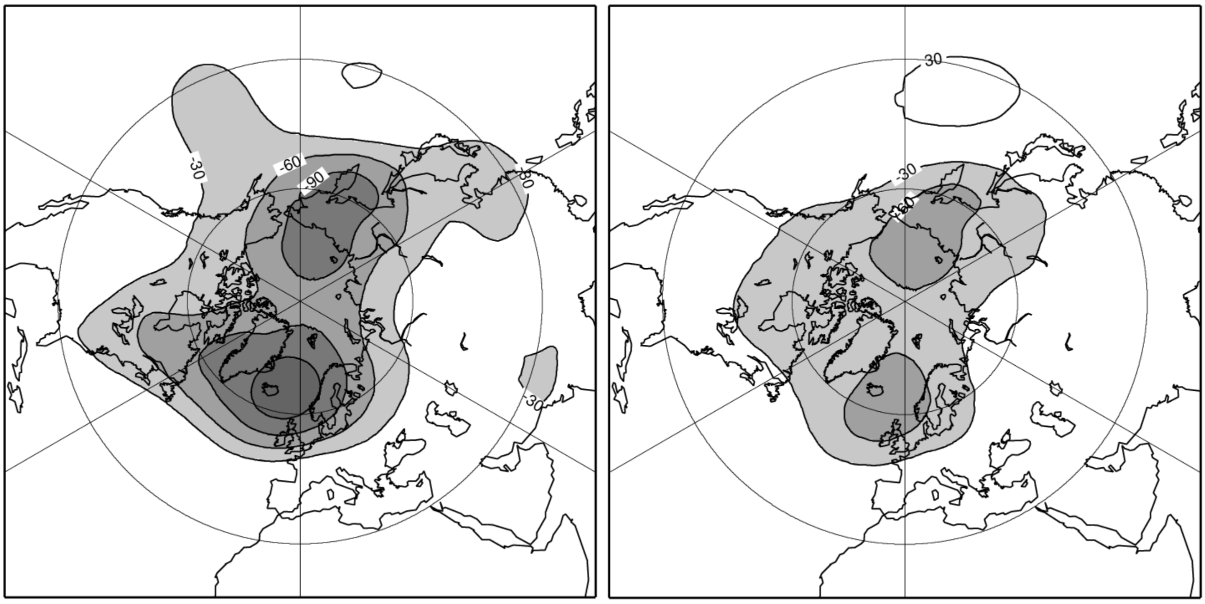

Figure 1: DJF mean error in E2 (left) and E3 (right) for 500 hPa geopotential height ; contour interval 30m, shading below -30 m

	30N-90N Z500	NAO	NAM	Nino3.4 SST	30S-30N Prec.
E2	0.27	0.24	0.13	0.89	0.54
E3 Q5%	0.30	0.23	0.39	0.90	0.54
E3 Q50%	0.35	0.43	0.52	0.91	0.56
E3 Q95%	0.40	0.60	0.64	0.92	0.57

Table 1: Anomaly correlation over 32 DJF for 500 hPa height (30N-90N), North Atlantic Oscillation (NAO), Northern Annular Mode (NAM), Nino3.4 sea surface temperature and precipitation (30S-30N)

References:

Cubasch, U., Hasselmann, K., Höck, H., Maier-Reimer, E., Mikolajewicz U., Santer, B.D. and Sausen, R., 1992 : Time-dependent greenhouse warming computations with a coupled ocean-atmosphere model. Clim. Dyn., 2, 55-69

Déqué, M., 2007a: Frequency of precipitation and temperature extremes over France in an anthropogenic scenario: model results and statistical correction according to observed values. Global and Planetary Change, 57, 16-26

Guldberg A., Kaas, E., Déqué, M., Yang, S. and Vester Thorsen, S., 2005: Reduction of systematic errors by empirical model correction: impact on seasonal prediction skill. Tellus, 57A, 575-588

Update of JMA's One-month Ensemble Prediction System in March 2011

Masayuki Hirai*, Kengo Miyaoka, Ryoji Nagasawa and Noriyuki Adachi
Climate Prediction Division, Japan Meteorological Agency
E-mail: m-hirai@met.kishou.go.jp

Introduction

Since March 1996, the Japan Meteorological Agency (JMA) has operated the one-month ensemble prediction system (EPS), whose global numerical prediction model is a lower-resolution version of that used for the short-range prediction system (JMA-GSM). In a related development, the Agency formulated a global model with a new dynamical frame and adopted it in the operation of JMA-GSM (Miyamoto 2009). After the update, the one-month EPS was also updated on 4 March, 2011. However, no change was made to the main specifications, such as the resolution and ensemble size (TL159L60, 50 members).

Main changes from the old system

The main changes introduced by this update are outlined below.

* Implementation of a new dynamical frame (with reduced Gaussian grids)

A reduced spectral transformation (Juang, 2004; Miyamoto, 2006) was introduced, and the numbers of grid points and wave number components in the model were lowered to shorten its execution time. The precision of the dynamical process was also improved by setting a number of parameters for transformation between spectral and grid-point space as the quadruple-precision floating type and by refining other dynamical processes.

* Update of climatological aerosol total optical depth

The climatology for the aerosol total optical depth value used in estimating the direct effects of aerosols was updated. The data source for the climatology was expanded, the number of available satellite data was increased, and the method of performing estimation for data-poor areas such as high latitudes was improved.

* Minor change to land surface processes

Soil permeability was refined to improve the reproducibility of soil wetness in the snowmelt season.

* Extension of the hindcast period

Hindcast experiments have been executed using the new system with the target period extended from 1979 – 2004 to 1979 – 2009.

References

Juang, H. -M. H., 2004: A Reduced Spectral Transform for the NCEP Seasonal Forecast Global Spectral Atmospheric Model. *Mon. Wea. Rev.*, **132**, 1019 – 1035.

Miyamoto, K., 2006: Introduction of the Reduced Gaussian Grid into the Operational Global NWP Model at JMA. *CAS/JSC WGNE Research Activities in Atmospheric and Oceanic Modeling*, **36**, 06 – 09, 06 – 10.

Miyamoto, K., 2009: Recent Improvements to the JMA Global NWP Model. *CAS/JSC WGNE Research Activities in Atmospheric and Oceanic Modeling*, **39**, 06 – 09, 06 – 10.

Evaluation of the Genesis of Typhoon JANGMI for Modified Convection and Cloud Schemes in JMA-GSM: Comparison with T-PARC Special Observations

Takuya KOMORI * and Akira SHIMOKOBE

Numerical Prediction Division, Japan Meteorological Agency, Tokyo, Japan
Email: komori@met.kishou.go.jp

1. INTRODUCTION

For numerical weather prediction models, accurate forecasting of typhoon genesis is a crucial function. However, verification of vertical profiles for simulated typhoons over ocean areas is usually problematic due to a lack of observational data.

In 2008, observation using supplemental dropsondes deployed by manned aircraft was conducted as part of T-PARC (THe Observing system Research and Predictability EXperiment (THORPEX) Pacific Asian Regional Campaign) over the western North Pacific Ocean to investigate TC genesis, structural change, targeted observation and extratropical transition. Based on the dropsonde and satellite data obtained, this study was performed to evaluate the forecast performances of the operational Global Spectral Model (GSM) with revised parameterization schemes for TC genesis over the tropical western North Pacific Ocean.

2. EXPERIMENTAL DESIGN

Two experiments (CNTL and TEST) were conducted to compare 36-hour forecast performance levels. The CNTL experiment was run using the operational GSM (TL959L60: 20-km horizontal resolution, 60 layers) in which a convection scheme (the prognostic Arakawa-Schubert scheme with a spectral cloud ensemble) and a large-scale cloud scheme (cloud fraction is diagnosed following an assumed probability density function (PDF)) were implemented. In the TEST experiment, the convection and cloud schemes were modified (see Komori and Yoshimoto 2012).

3. VERTICAL CROSS-SECTION EVALUATION

Figure 1 (a) shows the locations of the T-PARC special observations for Typhoon JANGMI (the 15th typhoon of 2008; T0815) overlaid onto MTSAT satellite images, and Fig. 1 (b) shows a satellite image of the area around JANGMI during the development stage. The vertical cross section of dropsonde observations along the black line in Fig. 1 (b) reveals high relative humidity (RH) at the center of JANGMI and strong wind peaks around it (Fig. 2 (a)).

Figures 2 (b) and (c) show the results of the CNTL and TEST experiments, respectively, corresponding to the observations shown in Fig. 2 (a). In the CNTL data, RH is lower around the center of JANGMI and above the 900-hPa level in contrast to the observation results, which suggests weak transport of water vapor from the convective boundary layers to the free atmosphere by moist convection. Conversely, the TEST data show that the higher RH seen at the TC center in the observation data is reproduced successfully. In the modified convection scheme introduced in TEST, the upward mass flux varies depending on RH, which may be a significant contributory factor to this improvement.

Concerning wind speed, TEST forecasted strong wind peaks around the center of JANGMI corresponding to large low-level vorticity causing organized precipitation, whereas CNTL did not forecast such peaks (not shown).

4. PRECIPITATION EVALUATION

Figure 3 shows the distributions of 24-hour cumulative precipitation for CNTL and TEST in comparison to Tropical Rainfall Measuring Mission (TRMM) satellite and Global Precipitation Climatology Project (GPCP) data. The other typhoon seen in the figure is HAGUPIT (T0814), which made landfall around the same time as JANGMI was generated.

For CNTL, spurious precipitation was caused by a large-scale cloud scheme (not shown) in addition to the weak convection and higher RH in the lower atmosphere. In the TEST experiment, distribution around JANGMI was reproduced better than in the CNTL experiment, and spurious precipitation in other areas was suppressed. The organized precipitation seen in TEST suggested large vorticity, which is consistent with the results for wind speed and RH shown in Fig. 2.

Regarding precipitation around Hagupit, little difference was seen between the results of CNTL and TEST, although both experiments simulated more precipitation than TRMM and GPCP data. Accordingly, further research should be performed with a separate focus over ocean and land areas.

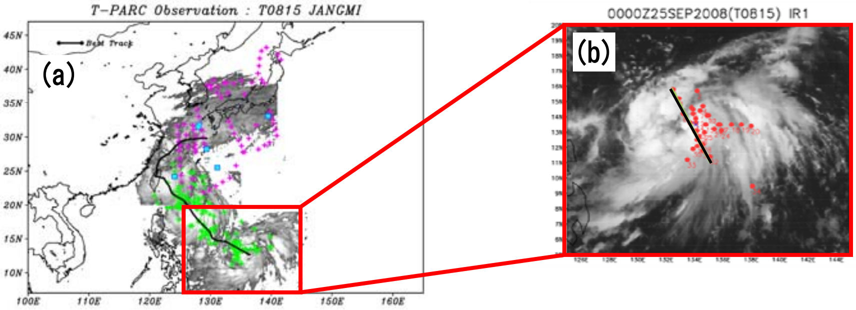

Figure 1. Locations of T-PARC special observations for Typhoon JANGMI (T0815) overlaid onto satellite images: (a) all dropsonde observations from manned aircraft (pink and green dots) and upper-air soundings (blue dots), and (b) dropsonde observations from manned aircraft (red points) around 00 UTC on 25 September, 2008. The black lines in (a) and (b) show the best track and the location of the vertical cross section shown in Fig. 2, respectively.

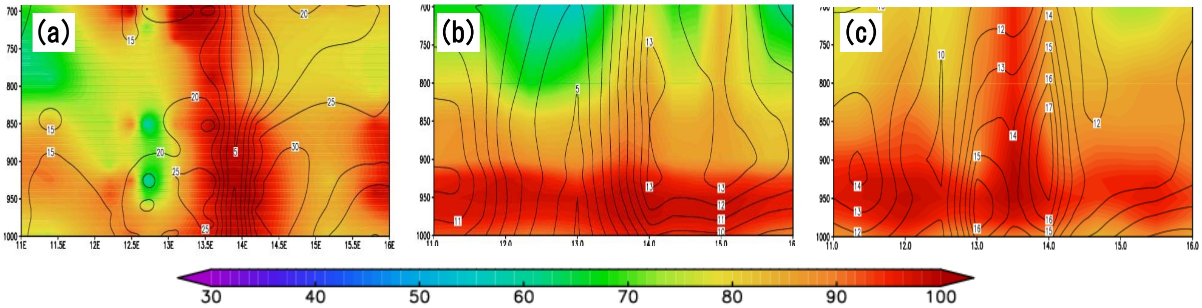

Figure 2. Vertical cross sections for relative humidity (shading) and wind speed (contours) around Typhoon JANGMI (T0815) estimated from (a) dropsonde observations, (b) CNTL and (c) TEST. (b) and (c) show 36-hour forecasts with an initial time of 12 UTC on 23 September, 2008.

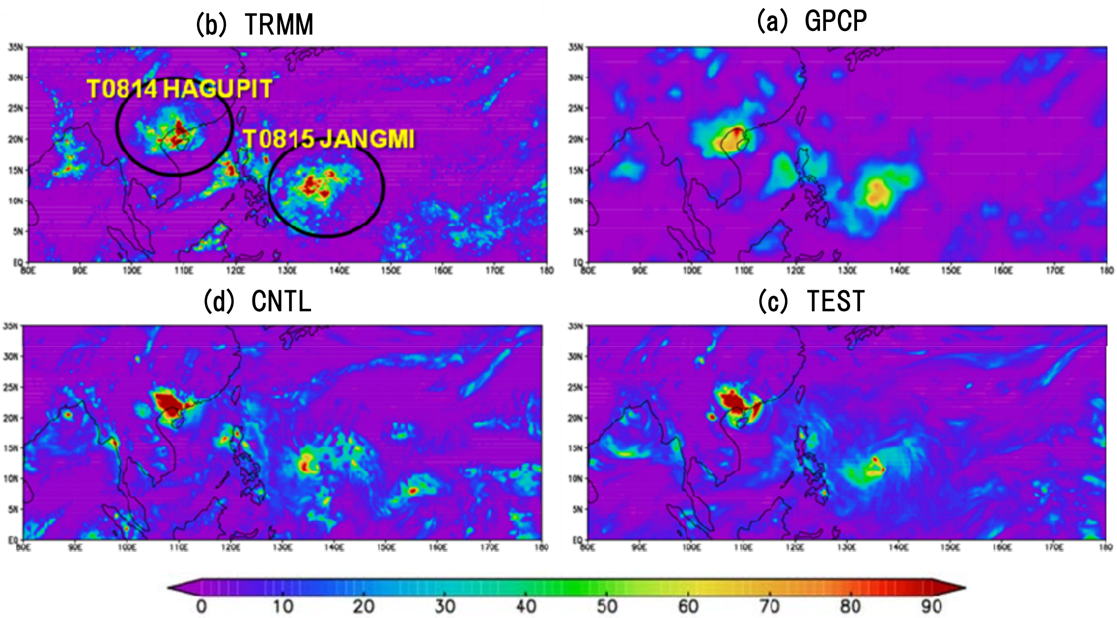

Figure 3. 24-hour accumulated precipitation [mm/day] during the landfall period of Typhoon HAGUPIT (T0814) and the genesis of Typhoon JANGMI (T0815) estimated from (a) TRMM satellite observations, (b) GPCP analysis, (c) CNTL and (d) TEST. (c) and (d) show 36-hour forecasts with an initial time of 12 UTC on 23 September, 2008.

REFERENCES

Komori, T. and K. Yoshimoto, 2012: Evaluation from a Perspective of Spin-down Problem: Moistening Effect of Convective Parameterization. *CAS/JSC WGNE Research Activities in Atmospheric and Oceanic Modeling*, **44**, in press.

Forecast Skill of MJO with the JMA's One-month Ensemble Prediction System

Satoko Matsueda and Yuhei Takaya
Climate Prediction Division, Japan Meteorological Agency
(E-mail: matsueda@met.kishou.go.jp)

Introduction

The Madden-Julian oscillation (MJO) is a dominant mode of intraseasonal variability in the tropics and influences weather and climate over not only tropics but also extratropics. The MJO has been thought to have a potential predictability up to one month and to be a forecast signal for this time scale. This article shows forecast skill and reproducibility of MJO in the hindcast of the JMA's one-month Ensemble Prediction System (EPS).

Data

The forecast data is a set of hindcasts with JMA's operational one-month EPS. The five-member hindcasts were carried out with the atmospheric general circulation model with the resolution of T_L159L60. Initial dates are 10th, 20th and the end of month during 1979 to 2001 (23-year). Verification data is 200-hPa (U200) and 850-hPa wind (U850) from JRA-25/JCDAS (Onogi et al. 2007), outgoing longwave radiation (OLR) provided by NOAA (Liebmann and Smith 1996) and precipitation from GPCP analysis (Huffman et al. 2001). A diagnostic package used in this verification was developed and offered by the U.S. Climate Variability and Predictability (CLIVAR) MJO Working Group (Gottschalck et al. 2010).

Verification method

A MJO index is computed following Wheeler and Hendon (2004). A combined Empirical Orthogonal Function (EOF) analysis is applied for daily fields averaged in the tropics (15S-15N) OLR and zonal wind (U850 and U200) for the period of 1979 to 2001. Before the EOF analysis, the long-term (23-year) mean and the most recent 120-day mean are removed, and each field is normalized by the square-root of its global mean variance. MJO phases (1-8) are defined as the eight sections in a PC1-PC2 phase space.
The MJO amplitude is defined as $\sqrt{(PC1)^2+(PC2)^2}$.

Verification scores are defined as follows:

$$RMSE(\tau)=\sqrt{\frac{1}{N}\sum_{t=1}^{N}\left((f_1(t,\tau)-a_1(t))^2+(f_2(t,\tau)-a_2(t))^2\right)}$$

$$COR(\tau)=\frac{\sum_{t=1}^{N}\left(a_1(t)f_1(t,\tau)+a_2(t)f_2(t,\tau)\right)}{\sqrt{\sum_{t=1}^{N}\left(a_1(t)^2+a_2(t)^2\right)}\sqrt{\sum_{t=1}^{N}\left(f_1(t,\tau)^2+f_2(t,\tau)^2\right)}}$$

$$PERR(\tau)=\frac{1}{N}\sum_{t=1}^{N}\tan^{-1}\left(\frac{a_1(t)f_2(t,\tau)-a_2(t)f_1(t,\tau)}{a_1(t)f_1(t,\tau)+a_2(t)f_2(t,\tau)}\right)$$

$$AERR(\tau)=\frac{1}{N}\sum_{t=1}^{N}\left(\sqrt{f_1(t,\tau)^2+f_2(t,\tau)^2}-\sqrt{a_1(t)^2+a_2(t)^2}\right)$$

where a_1 and a_2 are analyzed PC1 and PC2, f_1 and f_2 are predicted PC1 and PC2 and τ is forecast lead time. Root Mean Square Error (RMSE) denotes the MJO index error, and correlation coefficient (COR) denotes a phase error of the MJO. Phase error (PERR) denotes the bias of the MJO phase speed, and relative amplitude difference (AERR) denotes the bias of the MJO amplitude.

Verification result

Verification scores depending on lead time are shown in Figure 1. COR falls below 0.6 on day 13, which provides an estimate of skillful time range. Predicted MJO phase speed is faster and predicted MJO amplitude is smaller compared with the analysis. It is found that the model poorly represents eastward propagation of active convection over the Indian Ocean (Figure 2). Moreover, the model does not well reproduce the northward propagation of the active convection in the Indian Ocean (Figure 3).

Summary

The MJO forecast in the JMA's one-month EPS hindcast is skillful up to a lead time of 13 days. But the model fails to reproduce the realistic eastward and northward propagation of active convection. It is necessary to further improve the model for more realistic representation of the MJO.

References

Gottschalck, J. et al., 2010: A Framework for Assessing Operational Model MJO Forecasts: A Project of the CLIVAR Madden-Julian Oscillation Working Group. *Bull. Amer. Met. Soc.,* **91,** 1247-1258.

Huffman, G.J. et al., 2001: Global Precipitation at One-Degree Daily Resolution from Multi-Satellite Observations. *J. Hydrometeor.,* **2,** 36-50.

Liebmann B. and C.A. Smith, 1996: Description of a Complete (Interpolated) Outgoing Longwave Radiation Dataset. *Bulletin of the American Meteorological Society,* **77,** 1275-1277.

Onogi, K. et al., 2007: The JRA-25 Reanalysis. *J.Meteorol. Soc. Japan,* **85,** 369-432.

Wheeler, M. C., and H. H. Hendon, 2004: An all-season real-time multivariate MJO index: Development of an index for monitoring and prediction. *Mon. Wea. Rev.,* **132,** 1917-193.

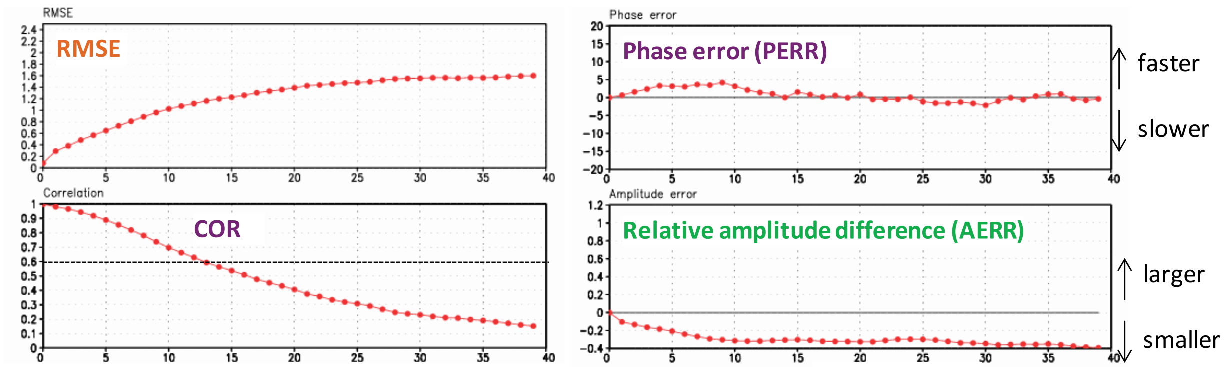

Figure 1 Verification scores of the predicted MJO index depending on the forecast time

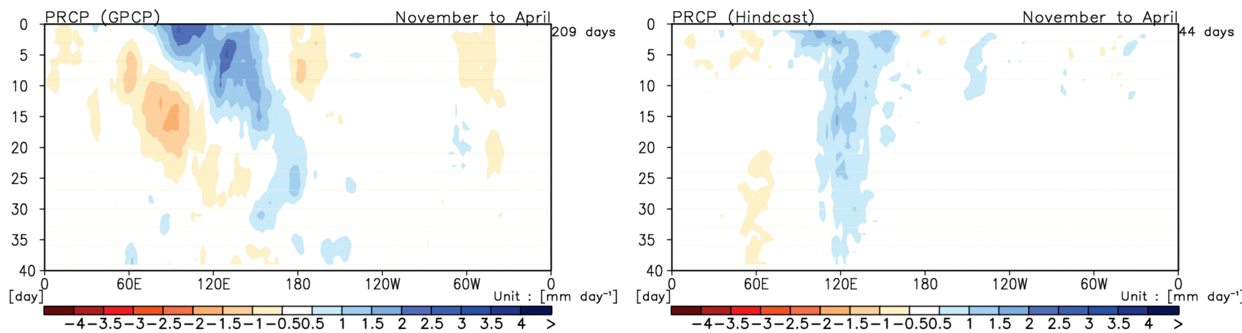

Figure 2 Composite of November-April precipitation averaged in the tropics (15S-15N) for analyses (left) and hindcast (right) started from phase 3 with the initial amplitude of > 1 σ

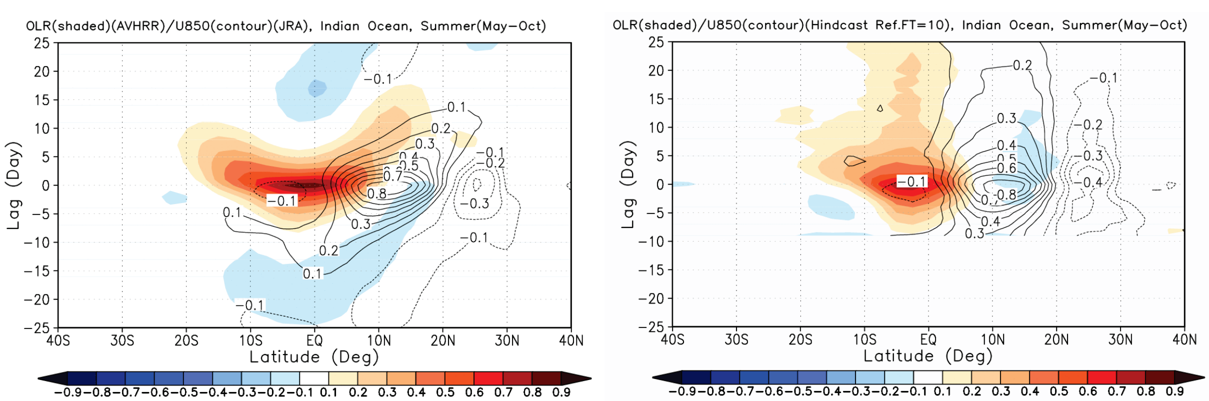

Figure 3 May-October lag correlation of intraseasonal OLR (color) and U850 (contour) averaging 80-100E against OLR and U850 at an Indian Ocean reference point (OLR:10S-5N,75-100E, U850:3.75-21.25N,68.75-96.25E) for analyses (left) and hindcast (right).

Introduction of a Stochastic Physics Scheme for Representation of Model Uncertainties to JMA's Typhoon Ensemble Prediction System

Yoichiro Ohta*, Hitoshi Yonehara, and Masayuki Kyouda****
*Environmental Modeling Center, National Oceanic and Atmospheric Administration
**Numerical Prediction Division, Japan Meteorological Agency
e-mail:Yoichiro.Ota@noaa.gov

Since February 2008, the Japan Meteorological Agency (JMA) has operated the Typhoon Ensemble Prediction System (TEPS), which is designed to improve track forecast targeting for tropical cyclones (TCs) in the Regional Specialized Meteorological Center (RSMC) Tokyo - Typhoon Center's area of responsibility within the framework of the World Meteorological Organization. The forecast model employed in TEPS is a low-resolution version (TL319L60) of JMA's Global Spectral Model (GSM) at TL959L60. TEPS adopts a singular vector (SV) method to generate its initial perturbations and calculates dry SVs targeting the mid-latitude area in the center's area of responsibility. It also calculates moist SVs targeting TC surroundings where moist processes are critical. A detailed description of the TEPS is given by Yamaguchi and Komori (2009) and Ohta (2011).

A stochastic physics scheme was introduced into TEPS as well as JMA's one-Week EPS (WEPS) in December 2010 after a related numerical experiment. (Yonehara and Ujiie, 2011) The scheme, which is based on Buizza et al. (1999), stochastically perturbs tendencies of parameterized physical processes.

As a result of this introduction, TEPS started representing model uncertainties in addition to initial data uncertainties. The experimental results show that the introduction makes the ensemble spread more appropriate in terms of the spread-skill relationship and improves forecast skill, especially over the tropics, in a very similar to WEPS. On the other hand, the results of experiments regarding the TC track forecast show that the introduction has a neutral impact on the size of forecast errors for the ensemble mean TC track (as shown in Figure) and the spread-skill relationship.

REFERENCES

Buizza, R., M. Miller, and T.N. Palmer, 1999: Stochastic representation of model uncertainties in the ECMWF Ensemble Prediction System. Quart. J. Roy. Meteor. Soc., **125**, 2887-2908.

Ohta, Y., 2011: Modification to Initial Perturbations of JMA's Typhoon Ensemble Prediction System. WMO CAS/JSC WGNE 2011 Blue Book.

Yamaguchi, M. and T. Komori, 2009: Outline of the Typhoon Ensemble Prediction System at the Japan Meteorological Agency. RSMC Tokyo-Typhoon Center Technical Review, **11**, 14 – 24.

Yonehara, H. and M. Ujiie, 2011: Stochastic physics scheme for model uncertainties in the JMA one-week ensemble prediction system. WMO CAS/JSC WGNE 2011 Blue Book.

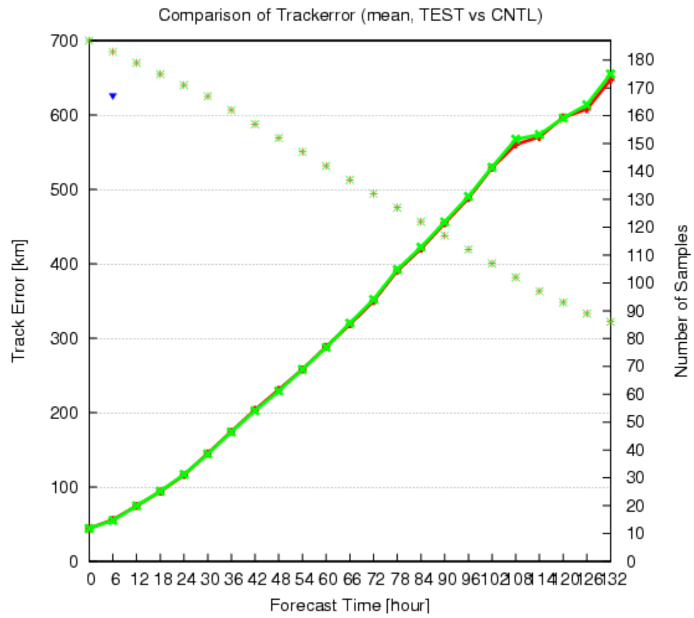

Figure : Mean position error of the ensemble mean TC track from TEPS. The horizontal axis shows the forecast range up to 132 hours ahead, and the green and red lines represent the results of verification for the current and previous systems, respectively. The crosses indicate the numbers of verified samples based on the vertical scale on the right.