Extended probabilistic Typhoon forecast in South China Sea and operational weather forecast via satellite communication

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Keywords: Risk management, real-time forecast, numerical weather prediction, ECMWF product, probabilistic forecast

Abstract. Significant predictability is found in medium-range weather systems over East Asia, particularly in those convective hazard weather events bringing numerous obstacles to the transportation and infrastructures. Based on a most advanced global numerical model product, we developed a real-time warning system to provide medium-range (5-15 days) forecast on danger events. The forecast is probabilistic to help the decision makers do gain/lost estimation. In 2007 and 2008 three flooding events on the Brahmaputra River were well predicted 10 days in advance. The medium-range genesis forecast skill of typhoon, a relative small-scale but much destructive weather system, is explored on examples of Megi and Doksuri. For both typhoons the maximum winds and minimum center pressure are well predicted as well as the tracks. The forecast bias might be due to the global model's resolution limit or the missing of statistical rendering.

Weather predictability in Asia monsoon region

Most areas of the eastern and southern Asian continent are significantly influenced by the monsoon circulation and associated heavy precipitation. Those seasonal precipitations usually take over more than 2/3 of the annual total value. Convective low-pressure weather systems are the major carrier to bring the moisture and energy from ocean to the continents. During this process, great floods introduced by heavy precipitation rate or the Tropical Cyclones are the major hazard disasters attacking vulnerable coastal Asian countries frequently. Among those disasters a famous one is the super typhoon Nargis who claimed more than 18,000 lives in Burma in May 2008.

Predictability in the 5-15 day range has been found in Asian monsoon rainfall, particularly in those great river basins suffering quick flash floods [1, 2]. The US Agency for International Development (USAID) has funded an exploratory project to provide advanced warning of Brahmaputra and Ganges flooding for Bangladesh on time scales ranging from daily to seasonal. Later on this work was carried out by the Climate Forecast Applications Network Inc.[1] (CFAN). The flood forecast model is based on a statistical rendering of the European Centre for Medium-Range Weather Forecasts (ECMWF) Variable Resolution Ensemble Prediction System (VAREPS) output and has been operational in Bangladesh since 2004. The background of such ensemble experiment encourage us assume that the mean value of the multi-ensemble forecasts best indicates the target's expected value.

Real-time typhoon forecast in northwest Pacific Ocean

Encouraged by the skill found in flooding forecast, the same system has now been adopted to consider typhoon (max wind speed > 64 knots) forecasting in the Asian monsoon areas. We apply the Vitart's algorithm [3] to retrieve the tropical cyclone activity from the ECMWF global-scale

[1] http://www.cfanclimate.com

grid model. Multiple TC characteristics, including spatial surface pressure and wind speed distribution, genesis location, and tracker routing pattern, are taken account of for identification. During last three years the CFAN model never missed any TC even the category is low in tropical depression (TD, max wind within 26~35 knots). Example of Megi's cyclonegensis forecasting made in 6- and 11-day lead time are given here.

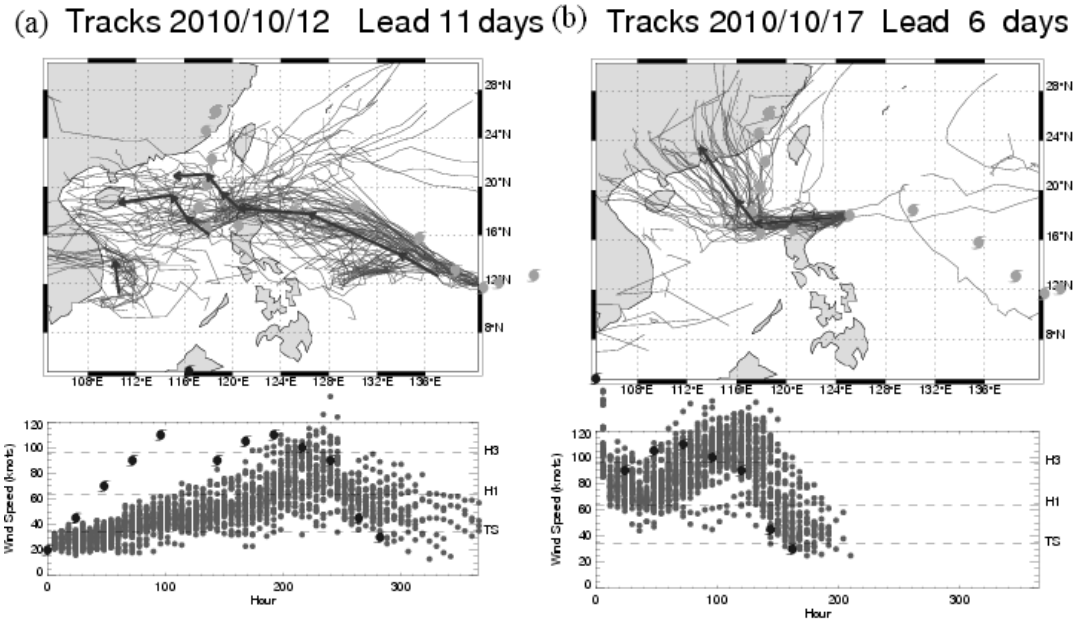

Figure 1 (a) ensemble TC forecast for northwest Pacific Ocean on Oct 12th 2010 (11 days prior to the super typhoon Megi's landfall), thin gray lines and solid black arrows indicate all possible future TC moving tracks and their mean value. The observed TC central locations per six hour are marked by icons (b) same as (a) but initialized on Oct 17th

In the upper panel of Fig. 1 (a), each individual TC track forecast, detected from either of 51 ensemble experiments, is marked by a thin gray line. Similar to the streamflow forecast, we calculate the multi-ensemble mean TC center locations, connected by the solid black arrows, to indicate the most possible future TC center routing. Though the arrow trend does not exactly catch the turning point at 116E, 16N, the average track locations predict the approximate TC moving direction and the landing point very well (within 200km from the final destination) at a medium-range lead time of 10 days.

In the lower panel of Fig. 1 (a), the forecasted surface max wind and min pressure per six hours are plotted in gray dots together with the real observation in dark TC icons (retrieved from Joint Typhoon Warning Center achieves). As indicated by forecasts and observation, the cyclone's max wind rapidly dropped down after its landfall. The forecast skill is surprisingly good considering the lead time length and the fact that the cyclone eye radius is very close to the model's spatial grid distance (one degree, around 100km). At this resolution we can not expect the simulation exactly replicates the detailed structure of a relative small-scale weather system.

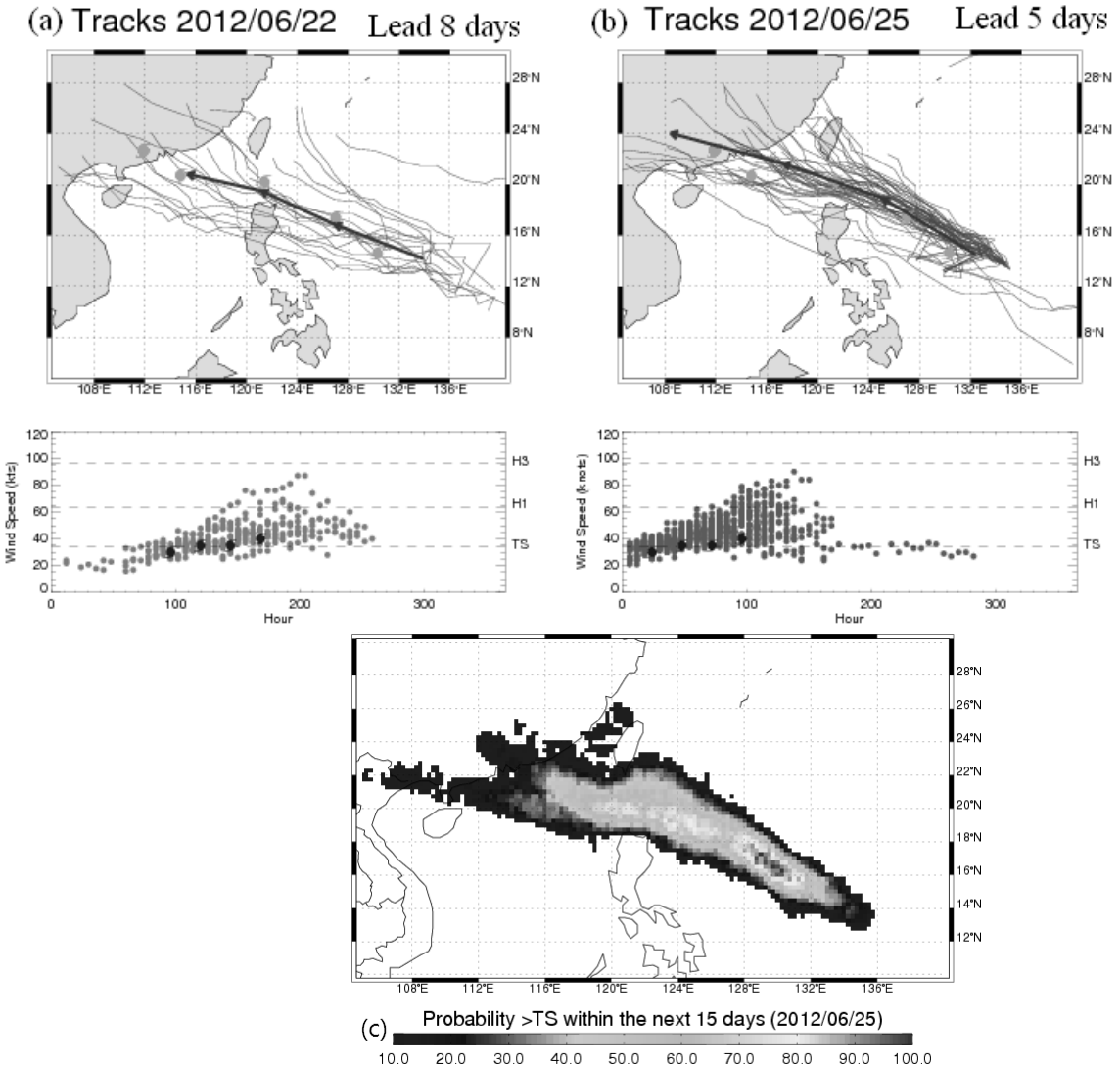

Figure 2 (a) ensemble TC forecast for Western Pacific on UTC1200Z, June 22nd, 2012 (8 days prior to the TS Doksuri's landfall), (b) same as (a) but initialized on June 25th, (c) the TS frequency distribution map forecast on June 25th 2012

This model has been providing operational TC pre-genesis forecasting from 2011 and shows great skills during each cyclongenesis event. Fig. 2 shows the TC forecast map over the northwestern Pacific Ocean on June 22nd 2012 in (a) and June 25th in (b). Some tracks have a close genesis location and similar moving directions, those tracks can be categorized as a single cluster. Each cluster indicates a simulated future TC on developing. To better illustrate the most possible TC movement, we collect all ensembles within one cluster and make the cluster-mean daily track locations and connect them by solid arrows. In either panel (a) or (b), the anticipated movement of TS Doksuri, which made landfall at Pearl River mouth on June 30th 2012 and greatly affected the maritime management, can be located in advance by one series of arrows, i.e. a track cluster, moving toward South China. Similarly, in the lower panels the forecast wind speed spread of the Megi-like cluster, are displayed. It is found that, though the TS Doksuri was officially formed and named on June 26th, but its magnitude developing and moving trend can be somewhat predicted much earlier. Reasonably, when the lead time is getting short, both the ensemble track and wind speed forecasts are improved.

If the forecast TC track deviates greatly during a particular period, the simple location-average method can not represent the highest possible TC passage. Realizing this, we construct the TC frequency distribution map. At each grid point, the number of passing-by TC during the next 15 days is counted and divided by the total simulated TC numbers from all ensembles. This uniformed probability, from low to high, is represented in shading area from dark to pale in Fig. 2(c). In this

way, the palest area inside the black surrounding indicates the most suspected place toward TC warnings in the future 15 days.

We note that, in general, the TC forecast skill is less than the flood forecast made earlier. For skill improvement purpose, more works, including increase the model grid resolution or statistical rendering, are recommended.

CFAN's cooperation with (UN) hazard warning organization and business clients

Though models could estimate the super typhoon Megi landfall's date and location several days in advance, there is only very few early-warning was issued to the residents on perish threaten who were living in the coastal low-land area and close to Yangguang, Burma. The similar thing was happened in those potentially flood-affected areas of Bangladesh before 2003. There is still halfway from the technical aspect solution and the disaster-preparedness solution. Realizing this, from the very beginning, the CFAN group has built up a close conjunction with the Asian Disaster Preparedness Centre (ADPC), an inter-governmental non-profit research institute, and the Flood Forecasting and Warning Centre (FFWC), a department of Bangladesh government. Upon CFAN and ADPC's authorization, advanced notice of the floods forecast results, were communicated by FFWC to the unions by a planned cell phone network and further to the villages by a series flag alerts. Local officials had acknowledged that the flood forecasts were optimal in horizon [4]. Sponsored by Shell-USA Company and China National Offshore Oil Company Ltd.-Shenzhen, CFAN has been creating additional extend-range and more detailed system of typhoon forecast in Northern Atlantic Ocean and the South China Sea. These works, proved much skillful, are based on the physical diagnosis and statistical rendering of various ECMWF products.

Such early-warning system is now being developed and assimilated into more sophisticated transportation system like Intelligent Transportation Systems (ITS) or Geographic Information System for Transportation (GIS-T) to benefit regional economy and improve transportation safety. For example, if any driver wants to know the trend of surface wind speed and direction at a closest half degree latitude/longitude grid point, he could send an electronic inquiry, via either email or Inmarsat satellite F/C communication service, with phrase "/lat/xxx.x/lon/yyy.y/" to a specified address userID@cfanclimate.com. Then within 10 minutes, a responding message with the following framed text would arrive at the receiver, indicating the wind trend during the next five days. This service has been operational examined on multiple transportation carriers since Jan 2012 and get positive responses [5].

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LON114.5/LAT15.5/.5deg
052912Z/8NW/5SW/
053000Z/14S/12S/10SW/15W/
060100Z/10NW/6NW/7W/10SW/
060200Z/11SW/9W/6W/6SW/
060300Z/8S/8N/9N/10N/
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In June 23rd 2012, many vehicles were seen along a flooded street after rainfall in the most commercial district of Beijing, the capital city of China. Many cyclist and passengers are isolated in the street and tens of them lost lives. If a real-time hazard weather warning system was developed and applied to those vehicles at that time or in the future, many of the losses due to the adverse weather could be avoided or at least minimized.

Conclusion

With new development of probabilistic ensemble forecast, hazard weather events in Asian monsoon region such as great flooding or TS have been found containing operational predictability. CFAN research group developed methods to forecast those weather disasters at 15-day lead-time or

above. Such forecasts have been proved much skillful and operational during last five years. Besides providing warning for the residents in danger or big companies to make profit, we are keen to assimilate our products into more sophisticated transportation system like Intelligent Transportation Systems (ITS) or Geographic Information System for Transportation (GIS-T) to benefit regional economy and improve transportation safety.

Acknowledgment

This work is supported by the Fundamental Research Funds for the Central Universities and Introduction Research Funds of Dalian Maritime University. The ECMWF global weather model data applied in this paper are received under the agreement between CFAN and ECMWF.

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