Bureau of Meteorology ACCESS-S
Multi-Week Tropical Cyclone Guidance: Extended Skill

Overview

The Bureau of Meteorology makes available multi-week tropical cyclone (TC) strike probability forecasts http://access-s.clide.cloud/tropical_cyclones/ for use by National Meteorological Services from the Australian Community Climate Earth-System Simulator – Seasonal (ACCESS-S) model. For more information on ACCESS-S go to http://www.bom.gov.au/climate/ahead/about/model/access.shtml. While seasonal TC forecasts such as those at http://www.bom.gov.au/climate/cyclones/australia/ provide information on the potential number of TCs within a region, they do not provide information on when or where these TCs might occur within the season. Weekly TC forecasts provide finer scale probabilistic information outlining the chance of and potential location of tropical cyclone occurrence within a week 1-4 period.

The ACCESS-S tropical cyclone tracker identifies points on the globe which are conducive to cyclogenesis over a forecast period of weeks. To accomplish this, various thresholds for humidity, wind shear and circular motion need to be met and sustained. Outputs of the model are then presented in two ways: The first is a raw model forecast, which is a forecast based on the model 'world' only (which may not match the real-world exactly as all models have biases). The second, a calibrated forecast, is the raw model forecast adjusted to real-world historical climatology.

Currently week 2 (day 8-14) and week 3 (day 15-21) raw and calibrated forecasts are presented and updated each day within a region's tropical cyclone season. While there is significant prediction skill at week 1 these forecasts are not presented as they would occur at the same time as operational weather scale TC forecasts and therefore to avoid confusion week 1 ACCESS-S TC forecasts are not presented.

The raw and calibrated model forecasts should be considered together to capture the best forecast information available; a brief description of both available products is shown below followed by a brief interpretation guide.

1. Raw model tropical cyclone formation probability plots

Tropical Cyclone strike probabilities using a 27.2 knots or 50.4 km/h minimum wind threshold at 850 hPa are computed by finding the proportion of forecast model tracks which pass within 300 km of each grid point (the probability comes from running the ACCESS-S model 33 times per day and finding the number of times out of 33 the model forecasts a tropical cyclone at each location). Forecasts for the period 16 to 22 March 2020 are presented as an example (Figure 1). Note the greater precision available in raw model plots.

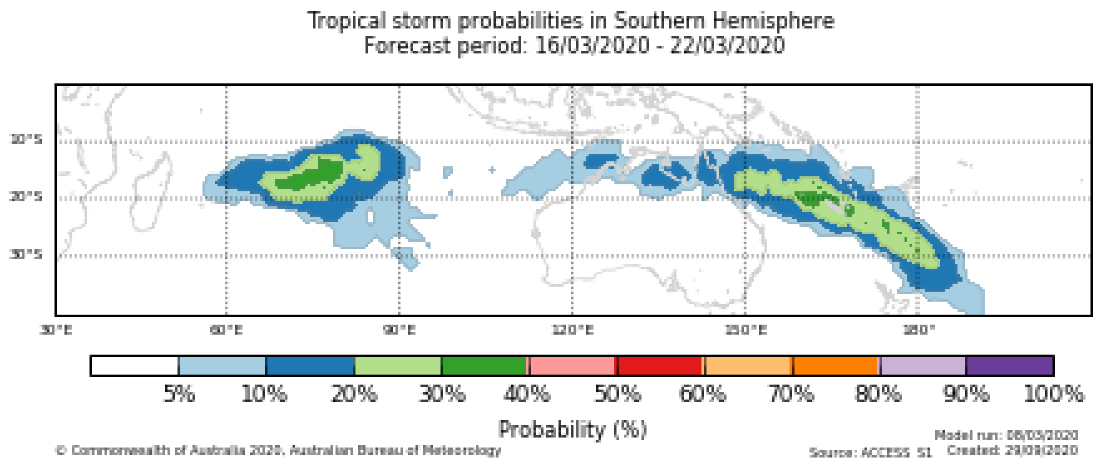

Figure 1. Raw model strike probability forecast for the southern hemisphere region.

2. Calibrated model tropical cyclone formation probability plots

Calibrated probabilities (Figure 2) have the best skill and reliability, particularly with week 3 and 4 forecasts (see skill section below). Calibration means the model is adjusted to the 'real world', which leads to a reduction in the chance of storm formation as ACCESS_S1 produces many false alarms. However, by constraining the model to the historical record some of the spatial resolution is lost (see the relatively large grids in Figure 2). A combination of the lower probabilities and coarser resolution that occurs through calibration means that we lose the very high probability events which are evident in the raw model probabilities.

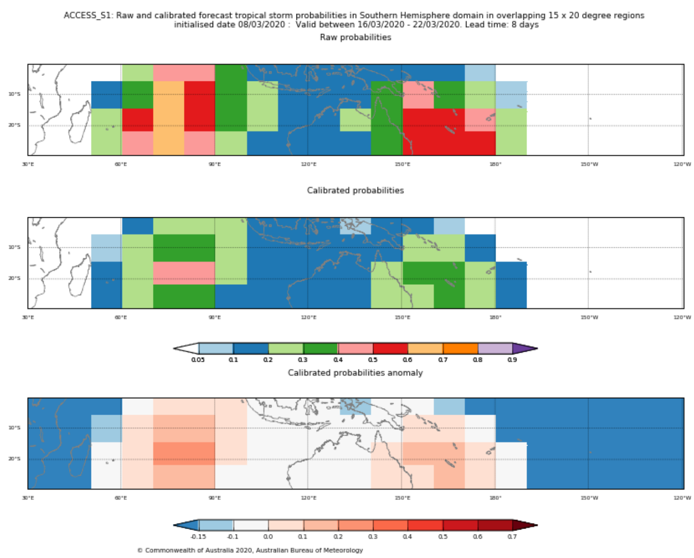

Figure 2. Calibrated model strike probability forecast in overlapping 15 x 20-degree regions. a) Raw model probabilities, b) calibrated model probabilities, c) calibrated model anomaly probabilities.

3. Interpretation guide

Figure 3 shows the difference from normal chance's and is intended to be used as the primary forecast tool for assessing the risk of tropical cyclone occurrence over a region, this is the same data as for the bottom panel of the calibrated forecast plot (Figure 2) shown in a little more detail.

The plot shows the chances of a tropical cyclone forming with respect to the historical occurrence. The historical computation of 'normal' probability is computed across the entire southern hemisphere. So generally, for any week between Nov-Apr, there is a 20% chance of a storm occurring somewhere in the southern hemisphere. This value has been shown to vary little regionally or temporally. The sub-regional detail comes from calibrating the forecast to historically observed events, highlighting areas which have a historical higher chance for TC formation.

The blue and white shading indicates the risk is low due to conditions not being favourable for cyclogenesis between 16 and 22 March 2020. The red shading indicates an increase in the chances for tropical cyclone formation with probabilities of 30% or greater a significant increased risk when compared to the historical record.

A forecast which maintains a steady chance of cyclone formation over two-three days is a good indicator of future cyclone genesis. Probabilities between 10-30% indicate increased cyclogenesis risk, with probabilities above approximately 30% indicating *significant* tropical cyclone formation risk (Figure 3) for a specific location.

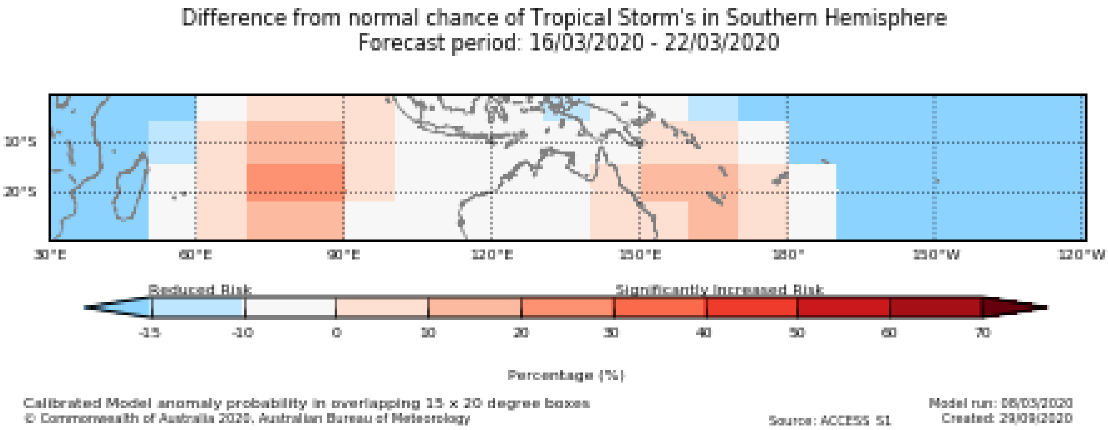

Figure 3. Calibrated model anomaly probability forecast in overlapping 15 x 20-degree regions

4. Model tropical cyclone formation probability skill assessment

Hindcast model skill for 1990-2012 has been assessed using the Brier Skill Score (Table 1) and reliability skill metrics. A forecast has skill if BSS is greater than zero, with 1.0 being the perfect forecast. A perfectly reliable forecast as shown in (Figure 4-7) would feature all points of the solid dotted line falling onto the diagonal (i.e. an event with a forecast probability of 40% will be observed 40% of the time). Table 1 shows greater than zero BBS scores for weeks 2-4 for both hemispheres and higher BBS scores for calibrated and northern North West Pacific forecasts. Even though week 4 southern hemisphere forecasts have skill as defined by the BSS metric, they are not presented as the skill is marginal.

Southern Hemisphere	**Week 2 (Days 8-14)**	**Week 3 (Days 15-21)**	**Week 4 (Days 22-28)**
Raw	0.128	0.044	0.023
Calibrated	0.155	0.096	0.074

North West Pacific	**Week 2 (Days 8-14)**	**Week 3 (Days 15-21)**	**Week 4 (Days 22-28)**
Raw	0.285	0.222	0.212
Calibrated	0.310	0.252	0.235

Table 1. Brier Skill Score for (top) the Southern Hemisphere, (bottom) the north west Pacific, for the cross validated model hindcast 1990-2012.

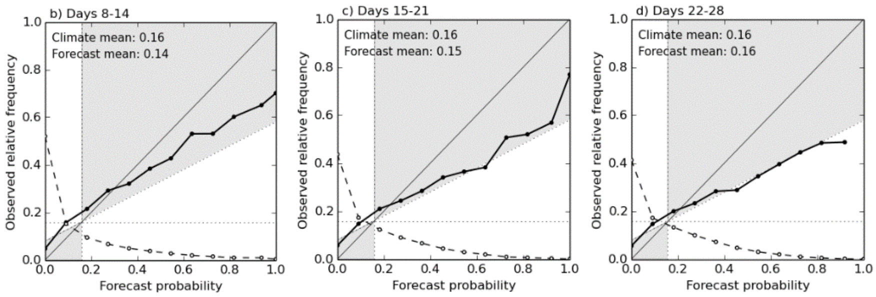

Figure 4. Raw model Southern Hemisphere reliability diagrams for hindcast period 1990-2012. a) Days 8-14, b) Days 15-21, c) Days 22-28.

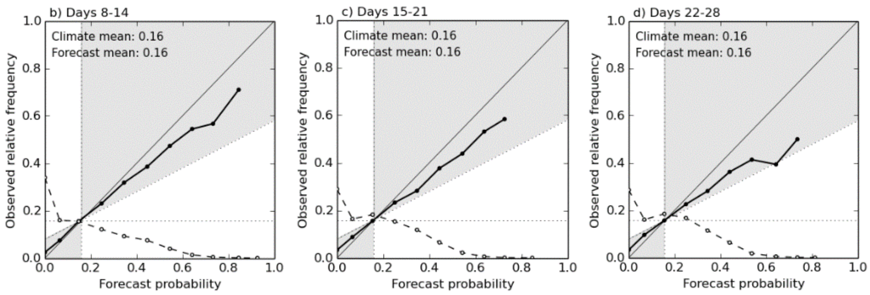

Figure 5. Calibrated model Southern Hemisphere reliability diagrams for hindcast period 1990-2012. a) Days 8-14, b) Days 15-21, c) Days 22-28.

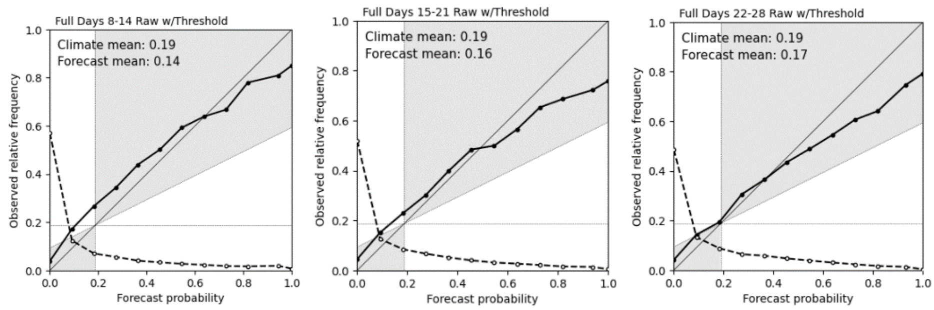

Figure 6. Raw model North Western Pacific reliability diagrams for hindcast period 1990-2012. a) Days 8-14, b) Days 15-21, c) Days 22-28.

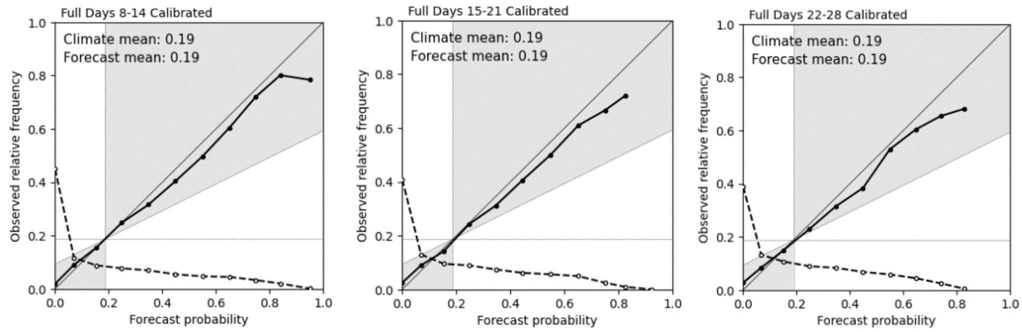

Figure 7. Calibrated model North Western Pacific reliability diagrams for hindcast period 1990-2012. a) Days 8-14, b) Days 15-21, c) Days 22-28.

5. Real-time skill assessment

Realtime skill in the Southern-Hemisphere has been assessed for the 2017-18 and 2018-19 seasons. Skill scores and reliability are shown below (Tables 3-4 and Figures 9-10). Note the real-time skill is superior to the hindcasts. This can be attributed to

1. Increased number of time the model is run per day. The real-time system is run 33 times per day/forecast, compared to the hindcast, for which the model is run 11 times per day.
2. Improved initialisation. The real-time system is initialised using the atmospheric analysis computed using the Australian Bureau of Meteorology's global Numerical Weather Prediction system. The hindcast is initialised using ERA-interim re-analysis.

Southern Hemisphere (Realtime)	**Week 2 (Days 8-14)**	**Week 3 (Days 15-21)**	**Week 4 (Days 22-28)**
Raw	0.193	0.093	0.075
Calibrated	0.187	0.100	0.081

Table 2. Brier Skill Scores for real-time Southern Hemisphere forecasts during the 2017-18 and 2018-19 seasons.

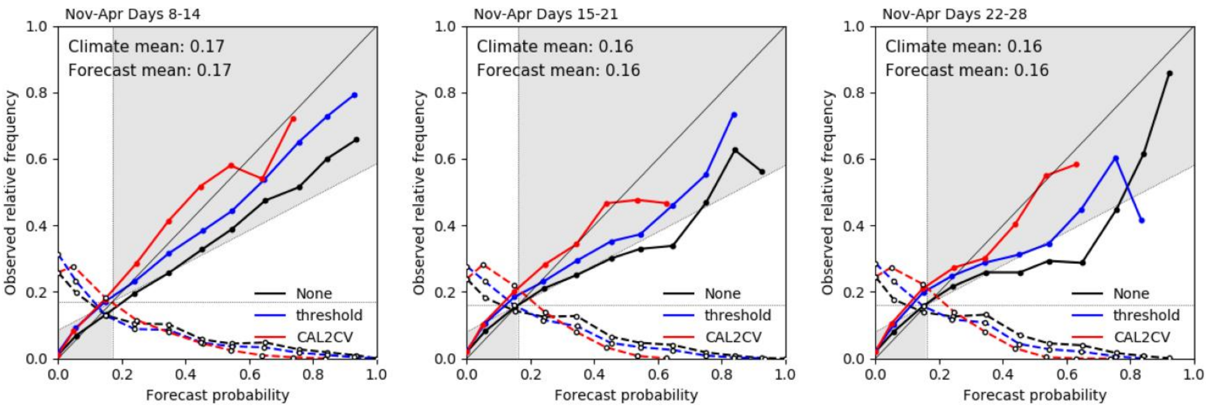

Figure 9. Realtime forecast reliability for all tracks (black), tracks with the windspeed threshold applied (blue) and calibration probabilities (red). From left to right: Days 8-14, Days 15-21, Days 22-28.

Recent studies also showed that creating a lagged-ensemble by combining track information from the previous days forecasts further improved forecast skill. Table 3 shows the increase in Brier Skill Score achieved by using a lagged forecast. The improvement in reliability is shown in Figure 10.

Southern Hemisphere (Realtime)	**Week 2 (Days 8-14)**	**Week 3 (Days 15-21)**	**Week 4 (Days 22-28)**
Lag 0 (default)	0.193	0.093	0.075
Lag 1	0.198	0.103	0.089
Lag 2	0.193	0.105	0.097
Lag 3	0.194	0.106	0.103

Table 3. Brier Skill Score for real-time Southern Hemisphere, (bottom) the north west Pacific, for the cross validated model hindcast 1990-2012. In this example Lag 1 uses forecasts

Here, "lag 0" refers to the default forecasts, "lag 2" includes ensembles from the previous day (hence forecasts include two days of data), "lag 3" includes forecasts from the two previous days (hence forecasts include three days of data) and so on. So, the lag 2 system is a 66-member ensemble, the lag 3 is a 99-member ensemble, and so on.

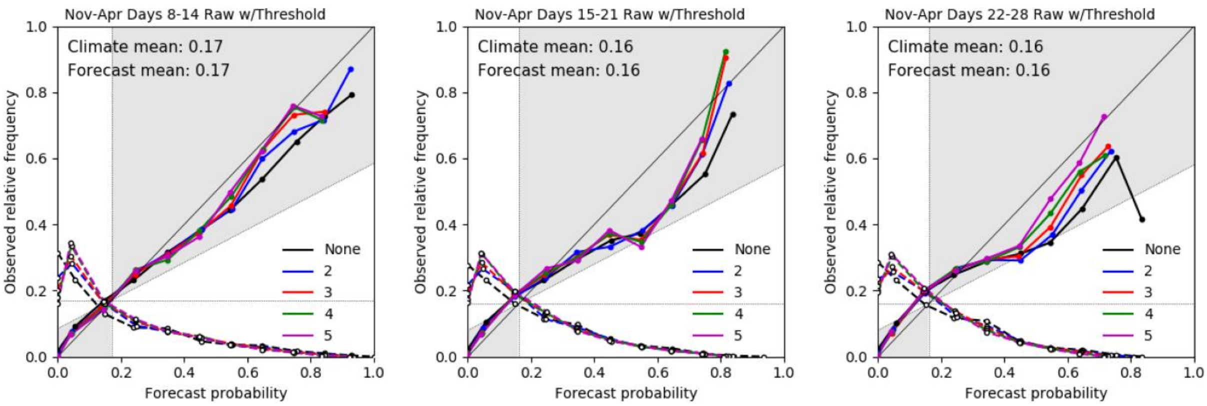

Figure 10. Realtime forecast reliability for tracks using the wind speed threshold for varying forecast lag. From left to right: Days 8-14, Days 15-21, Days 22-28.

Figure 10 shows that this increase in skill score comes at the expense of forecast resolution for days 8-14, and loss of skill at forecast probability ~= 0.5 to 0.6 for days 15-21 and 22-24

Therefore, we suggest issuing guidance using the previous two-three days of forecasts. Case studies show how the model can sometimes 'flip-flop' from day-to-day, but a forecast which maintains a steady chance of cyclone formation over two-three days is a good indicator of future cyclone genesis.