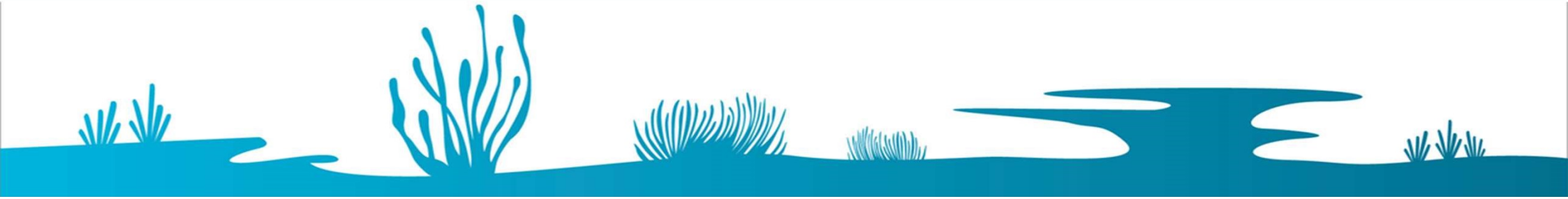
Climate and Oceans Support
Program in the Pacific

ACCESS-S Workshop

MODULE: Multi-week Tropical Cyclone forecasts



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Outline: ACCESS-S multi-week TC outlooks

- What can a multi-week TC outlook offer
- Multi-week TC outlooks around the globe
- Technical detail
- How do we get a probabilistic outlook
- Calibrating the model – what is a calibrated anomaly
- Model skill assessment
- Real time forecast examples
- What not to do when interpreting TC outlooks
- Guidance on interpretation
- Scenario: using climate observations and forecasts together
- Conclusion

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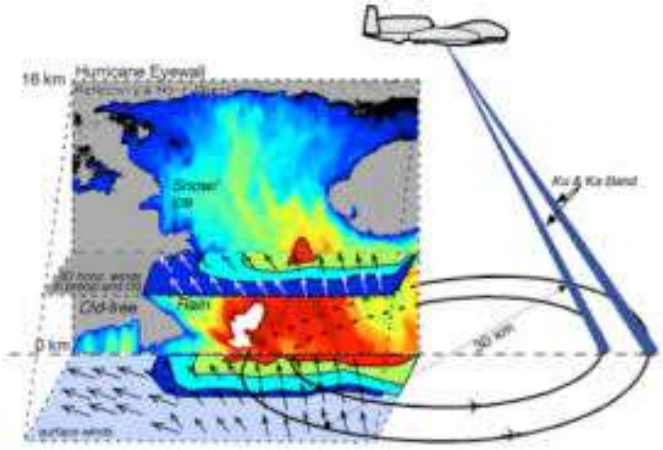
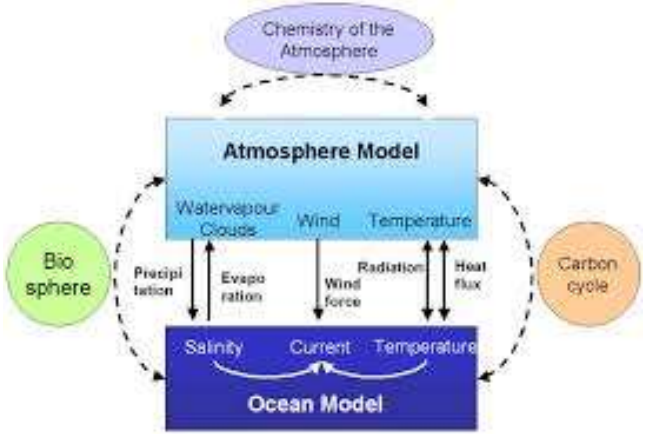
NWP vs Seasonal Climate Model for Tropical Cyclone forecasting: Bureau of Meteorology example

NWP (e.g. ACCESS-GE2)	Seasonal climate model (e.g. ACCESS-S1)
Sophisticated atmospheric data assimilation scheme to initialise the ensemble members	Simpler atmospheric data assimilation
Fixed ocean Sea Surface Temperatures	Dynamic ocean model (which is coupled to the atmosphere) which allows it to make long-range forecasts
Skill is higher, but it only runs out to 10 days	Skill is lower initially but it can be run out for multiple weeks





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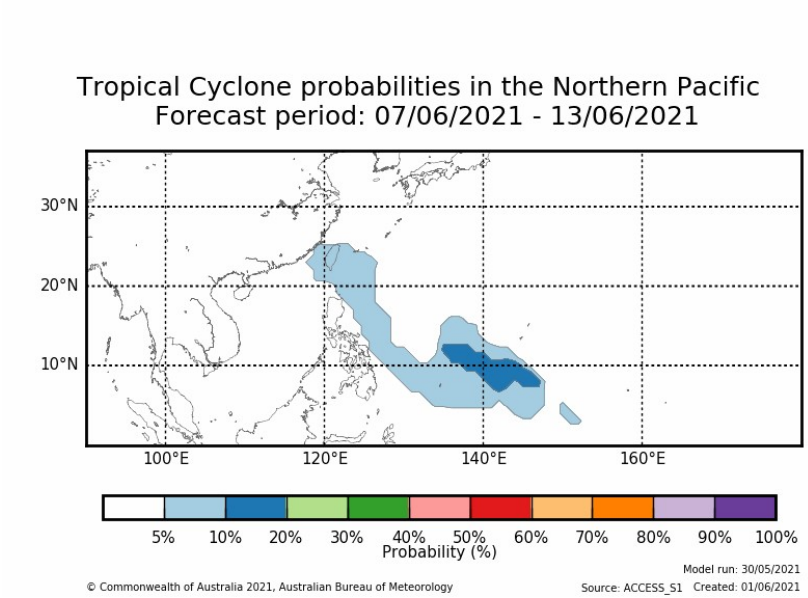
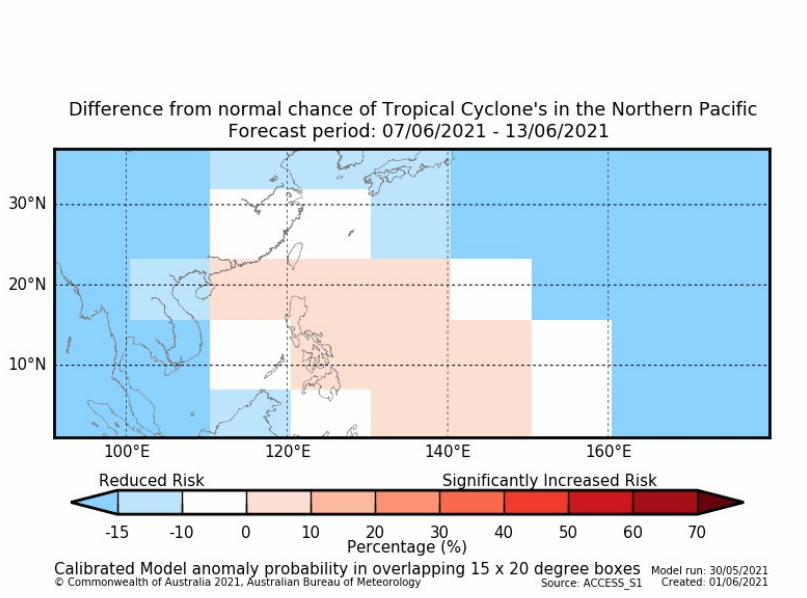
ACCESS-S multi-week TC outlooks key points

- Multiweek TC outlooks: Extending the forecast beyond NWP
- Outlooks are presented as probabilities similar to climate outlooks
- Week 1 (day 1-7): use your NWP forecast, this has the best skill
- Week 2/3 (day 8-14, day 15-21): probabilistic forecasts have good skill in the Pacific basin
- Week 4 (day 22-28): good skill in the Western North Pacific





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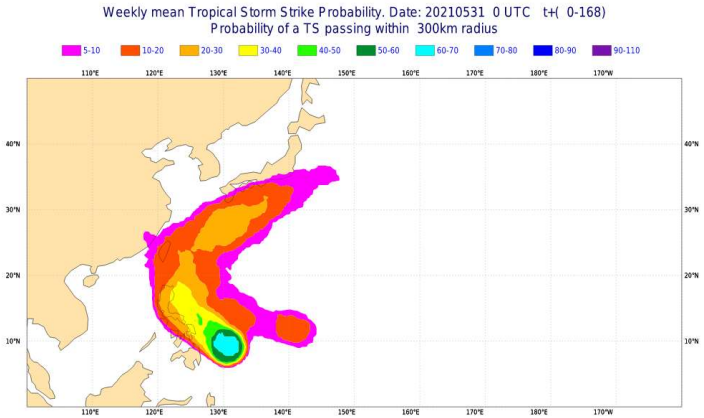
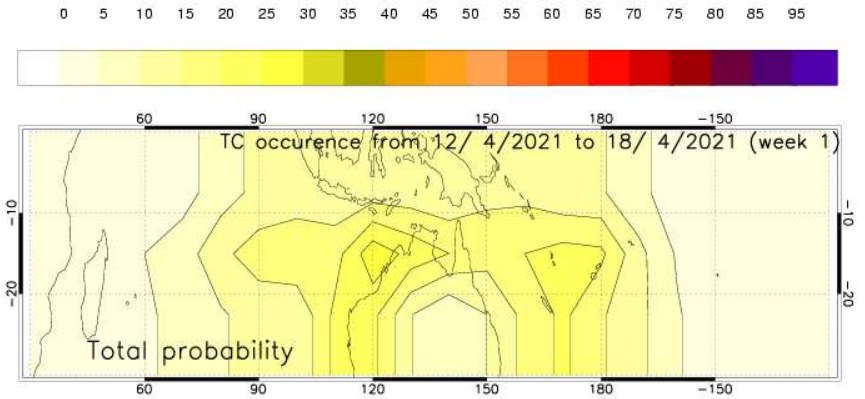
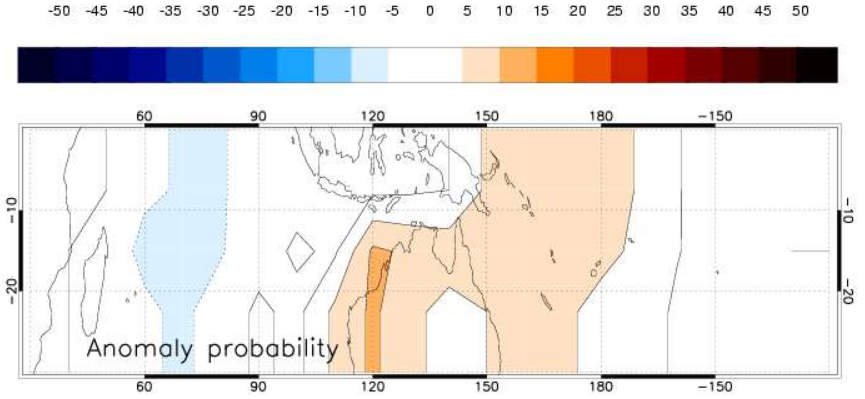
Where in the World: Tropical Cyclone outlooks







- Dynamical model forecasts issued by ECMWF (2012) and BoM (2020)
- Statistical-based forecasts offered by Meteo-France based on relationships between climate drivers such as the MJO and TC formation

- Dynamical models (ECMWF & BoM) do not currently have adequate skill at seasonal or TC season timescales. Therefore it is recommended that statistical outlooks are preferred at seasonal timescales

- On a multi-week timescale the MJO is a major driver of TC variability, and ACCESS-S shows high skill for predictions of the MJO meaning the model is able to 'reproduce the enhanced modulation of TC activity by the MJO in the Southern Hemisphere'

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ACCESS-S TC's: Technical detail

ACCESS-S1:

- Run 33 x per day (11 run for six months while the remaining 22 for 42 days)
- Provide guidance from days 4-28, though skill is highest early in the forecast period.
- TC tracker system needs 72 hours to identify a storm (no forecasts before day 4), conditions must be satisfied for at least 48 hours before a TC is considered to have formed.

- TC obs For calibration and verification purposes

- International Best Track Archive for Climate Stewardship – WMO (ICTrACS-WMO) 1981-2010

Real-time track data from NOAA for 2017 – 2019

https://journals.ametsoc.org/waf/article/35/5/1817/353805/Subseasonal-Forecasts-of-Tropical-Cyclones-in-the

ACCESS-S TC's: Technical detail

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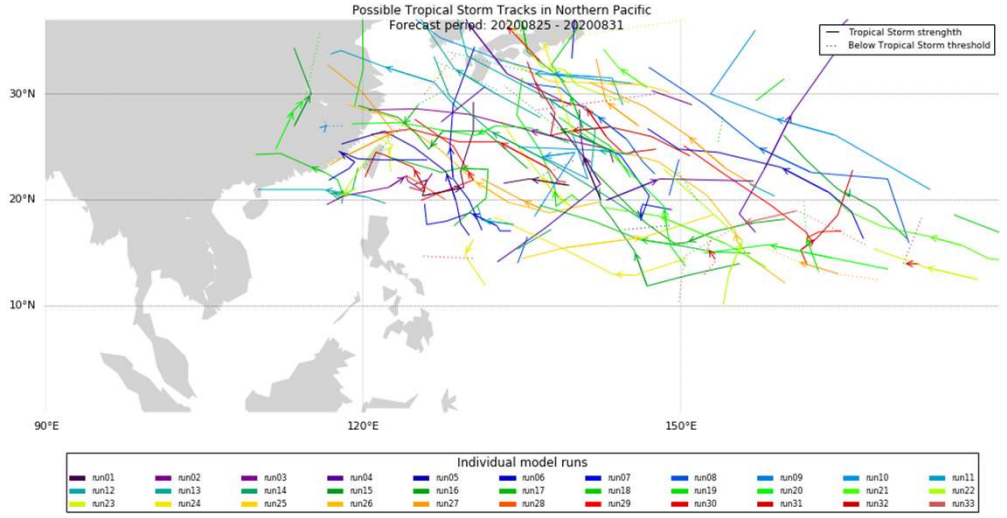
Tracker System:

- ACCESS-S uses the same cyclone tracker that is used in NWP TC prediction at the Bureau of Meteorology

- Cyclone tracker identifies points which are conducive to cyclogenesis. These include various thresholds for humidity, wind shear and circular motion that need to be met.

- Additionally these thresholds have to be sustained for a significant period



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ACCESS-S Cyclone Tracker

- The Okubo-Weiss-Zeta parameter (OWZ) tropical cyclone detection scheme developed by Tory et al. (2013) was used to compute the location of possible cyclones based on ACCESS-S atmospheric fields.
- OWZ was designed for use with coarse-resolution coupled ocean-atmospheric models. Instead of identifying storms using MSLP minima and vorticity maximum criteria (which are grid dependent and often not suitable for coarse-resolution coupled models) it searches for conditions conducive to cyclogenesis. These conditions are identified with the following atmospheric parameters: solid body rotation at 850 and 500 hPa, relative humidity at 950 and 700 hPa, specific humidity at 950 hPa, and low wind shear between 850 and 200 hPa. Points that satisfy certain thresholds for these parameters are identified and trajectories are computed that join each point in time.
- OWZ reproduces realistic TC genesis frequency and spatial distribution when applied to reanalysis data and the mean annual TC frequency is spatially similar to observations at the 95% level
- Threshold points were identified at every daily time step.
- When the OWZ tracker using its default thresholds[2] was applied to the ACCESS-S1 hindcast, too many storms were generated, especially at longer lead times. Applying the wind speed threshold significantly reduced the amount of forecast storms. Subsequent analysis found a threshold of 14 m/s gave the best improvement to Brier Skill Score (BSS) from weeks 2–4. Storms whose 850-hPa wind speed exceeded 14 m/s at least once during their lives were retained for BSS computation. Storms which failed to reach this threshold were discarded. (Increments of 2m/s were tested to see which threshold gave the best skill).

https://acp.copernicus.org/articles/13/2115/2013/

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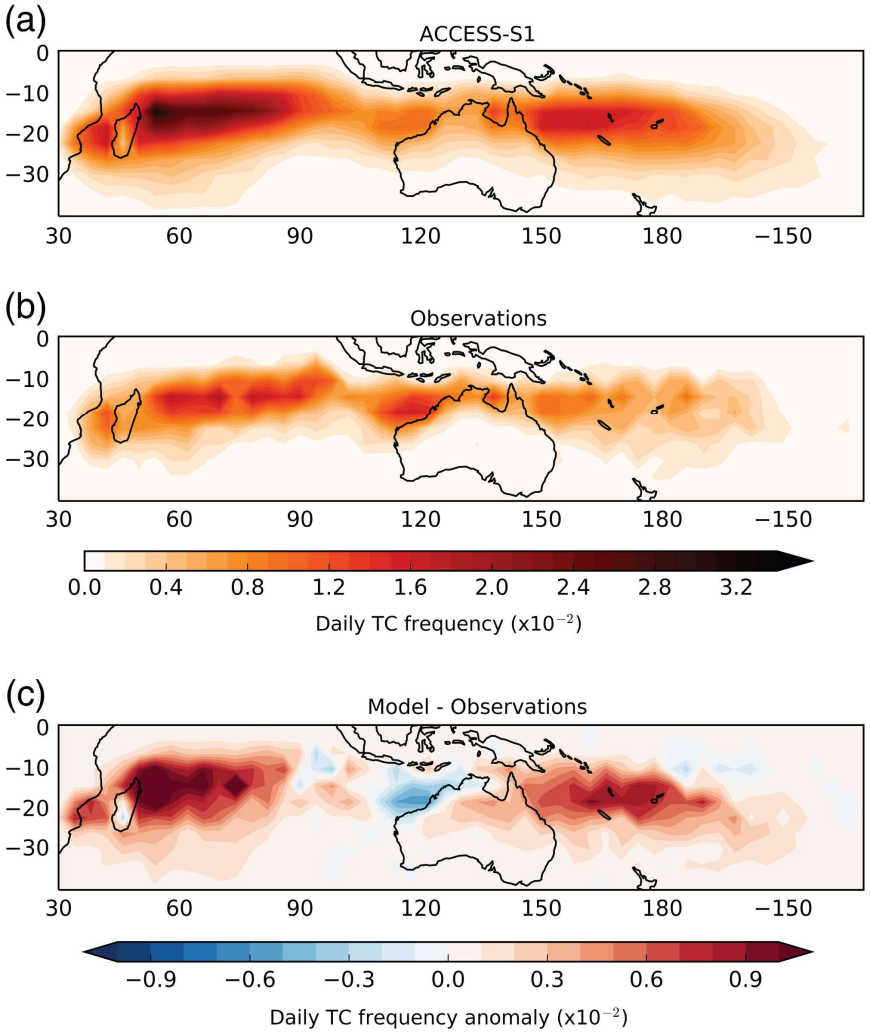
ACCESS-S: TC climatology



- NW Australia – bias likely related to the dry rainfall bias which develops in the first week of an ACCESS-S forecast, as well as a cold SST bias from month 2
- The positive bias also shows up in the UKMO model in similar location as ACCESS-S indicating that the bias may be in the model (known wet-bias in the South Indian Ocean)

Daily TC track frequency for (a) ACCESS-S1, (b) observations and (c) corresponding anomalies for forecast days 4–40 starting November 1, December 1, January 1 and February 1, 1990–2012. The total number of days used for ACCESS-S1 is 37,444 (23 years × 11 members × 4 start dates × 37 days) and for that observations is 3,404 (23 years × 4 start dates × 37 days)

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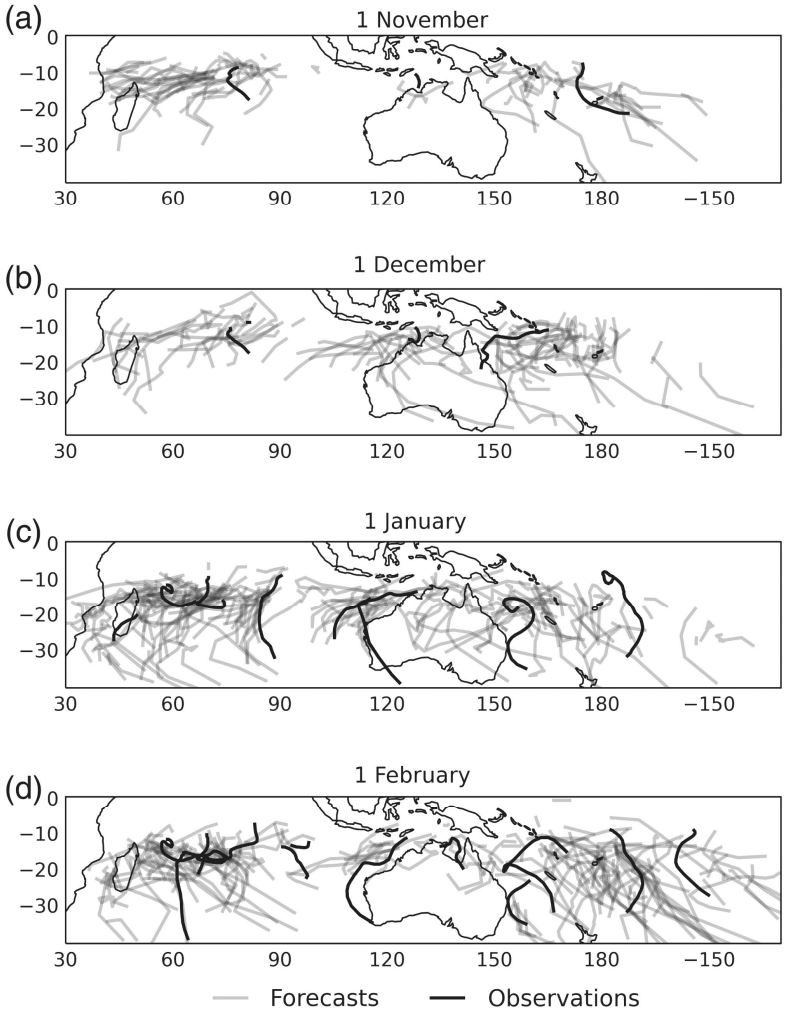
ACCESS-S V JTWC best-track 1990



- Realistic representation of location and direction of tracks
- ACCESS-S captures the increase in number of tracks in January and February

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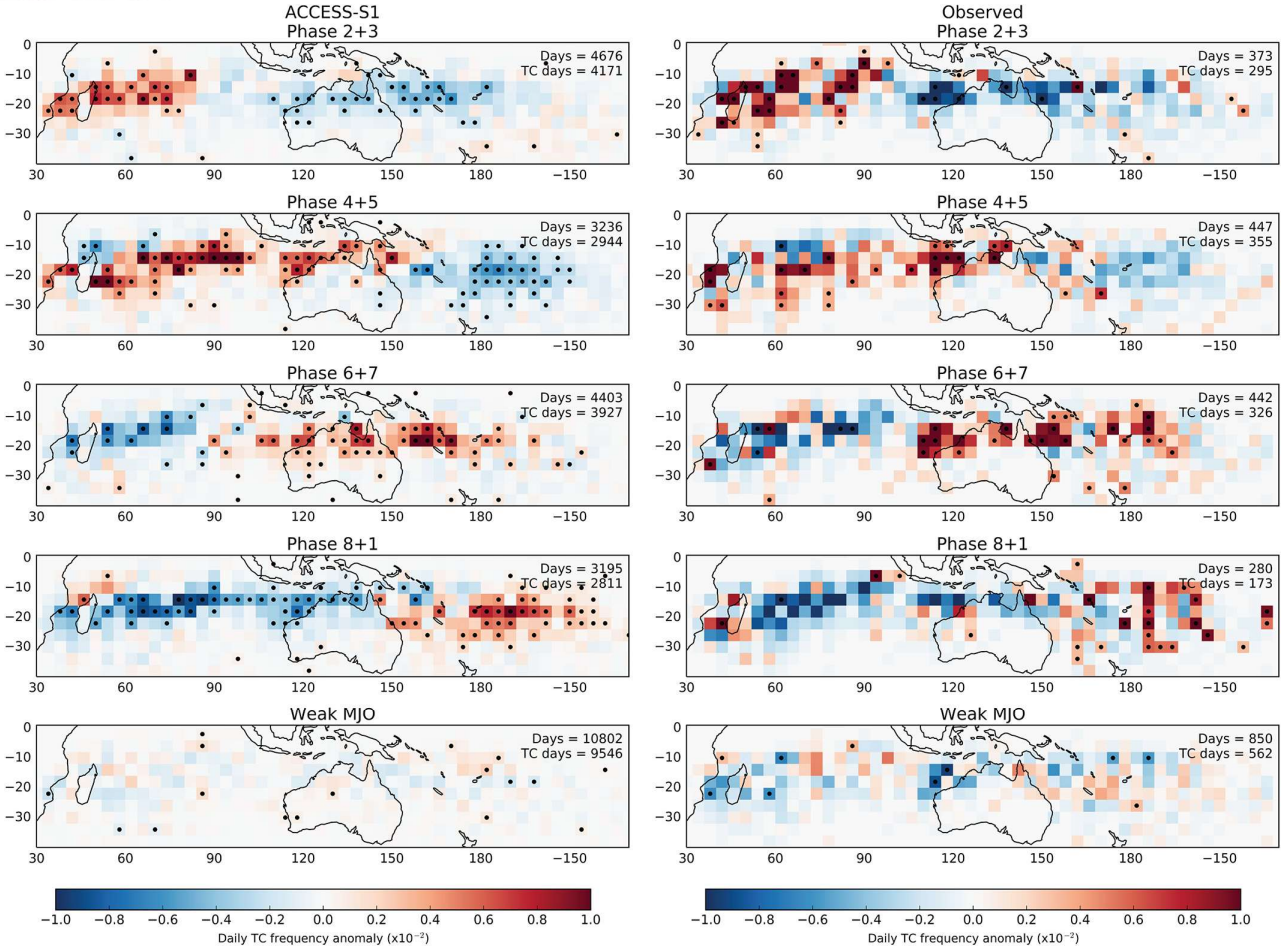
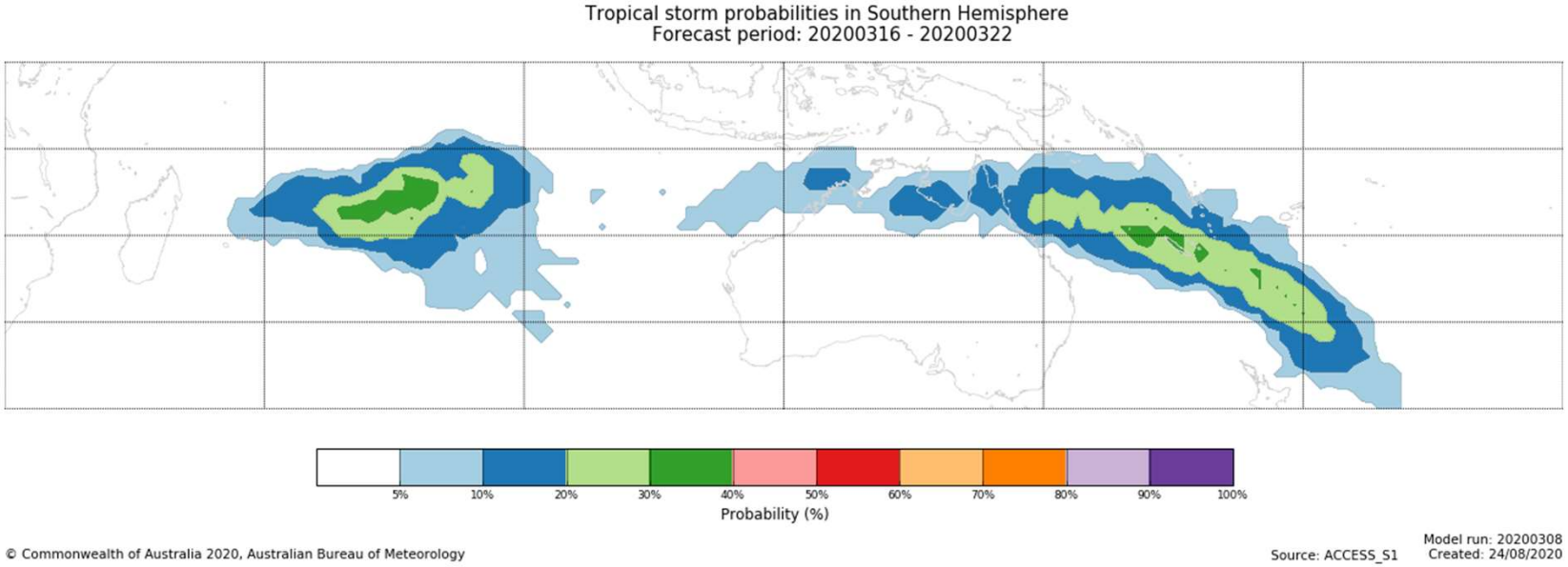
ACCESS-S V JTWC best-track 1990



- ACCESS-S captures the increase in TC frequency as the MJO moves eastwards
- Also capturing the suppressed TC activity before and after an enhanced MJO phase
- 850-hPa absolute vorticity (VORT), 600-hPa relative humidity (RH) and 850–200 hPa vertical wind shear (VWS) are well represented in ACCESS-S – this means a skillful MJO forecast

Daily TC track frequency anomalies for (top to bottom) MJO phases 2+3 (Indian Ocean), 4+5 (Maritime Continent), 6+7 (western Pacific) and 8+1 (Western Hemisphere and Africa) and when the MJO was weak (amplitude <1). Results are shown for ACCESS-S1 (left) and observations (right) for forecast days 15–40 starting on November 1, December 1, January 1 and February 1, 1990–2012. Black dots indicate where the TC track frequency anomaly is significant at the 95% level. The total number of days used for ACCESS-S1 is 26,312 (23 years × 11 members × 4 start dates × 26 days) and that for observations is 2,392 (23 years × 4 start dates × 26 days)

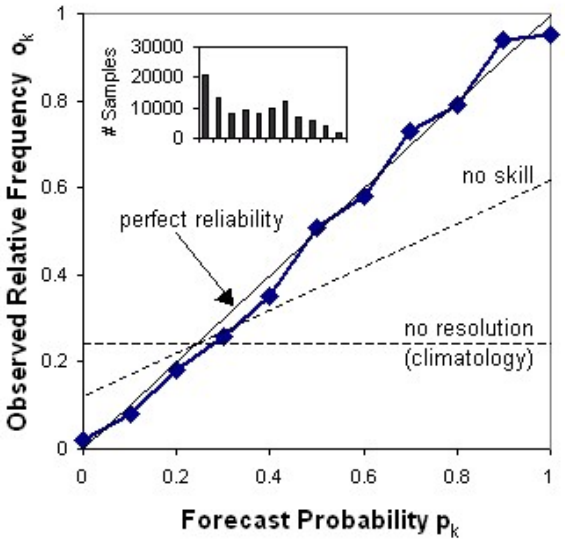
ACCESS-S: What is a TC probability



- Storm probability shows the number of tracks (ensemble member) in an area divided by 33 (number of times the model is run). E.g. if 15 storms passed within 300km of each other at a given location, the strike probability at that point = 15/33 = 45%
- Probabilities only includes tracks which met the threshold of 850 hPa wind-speed reaching 14 m/s
- Raw model probabilities have higher skill at shorter forecast periods, weeks 1 and 2 as compared to calibrated model forecasts.

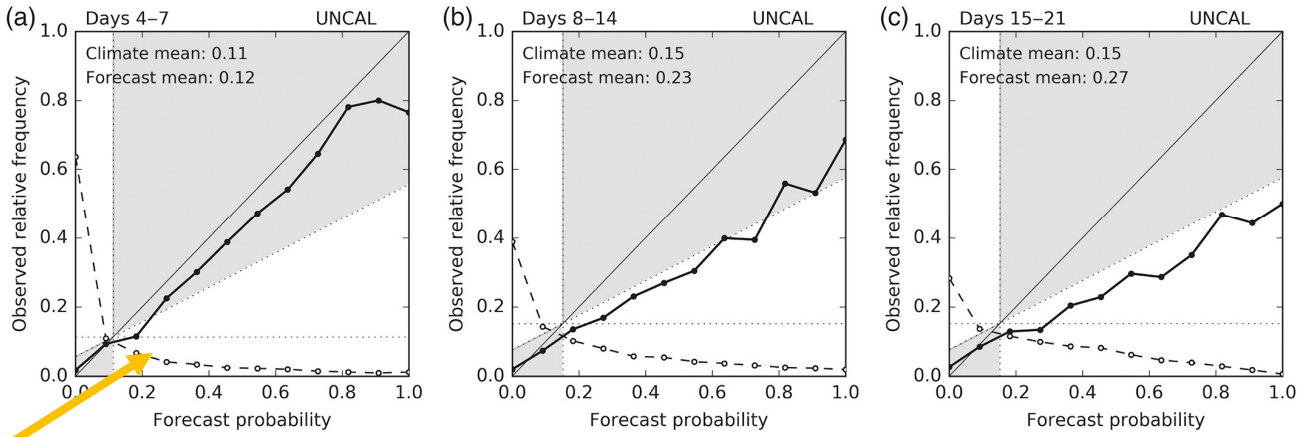
Brier Skill and Reliability: Southern Hemisphere

measuring the accuracy of probabilistic predictions



Relative frequency with which each probability bin was forecast

Southern Hemisphere raw model



SH	Days 4-7	Days 8-14	Days 15-21	Days 22-28
Raw	0.216	-0.042	-0.143	-0.185
w/ 14 m/s threshold	0.216	0.128	0.044	0.023
Calibrated	0.268	0.155	0.096	0.074

The **Brier score** is a measure of the reliability of the model by using mean-square error of probability forecasts for a binary event, such as the occurrence/non-occurrence of a tropical cyclone.

Range: -∞ to 1, 0 indicates no skill when compared to the reference forecast. **Perfect score:** 1

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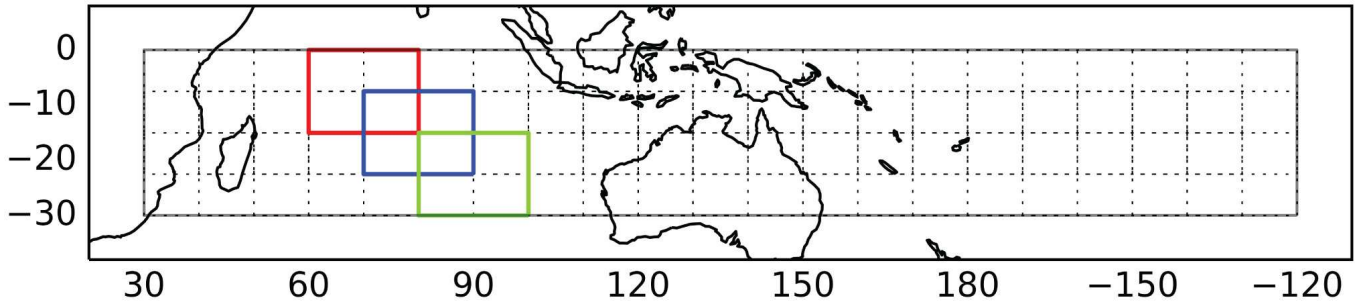
ACCESS-S calibration

- OWZ tracks from ACCESS-S1 forecasts are also calibrated.

- In this scheme, the forecast probabilities for each hindcast year are scaled by the ratio of the observed climate mean to the forecast mean of a TC occurrence – scaling factors

- In order to verify & calibrate we need a large region, the frequency of TCs spatially is small. The size of each verification region is 15° latitude × 20° longitude (20 overlapping boxes in the southern hemisphere)… the calibration scheme degrades the spatial resolution of the forecast tracks.

- The calibration scaling factors were averaged across the entire season (November–April) from 1990 to 2012.
- Scaling factors are computed for each forecast lead time (i.e., days 8–14, 15–21 and 22–28) and within each verification region.



- https://rmets.onlinelibrary.wiley.com/doi/10.1002/qj.3260

ACCESS-S calibrated forecasts

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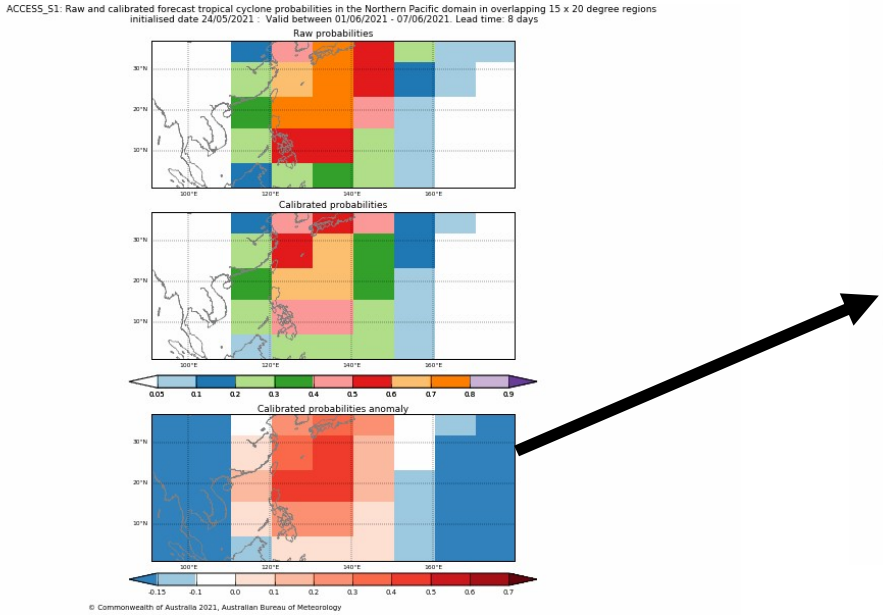

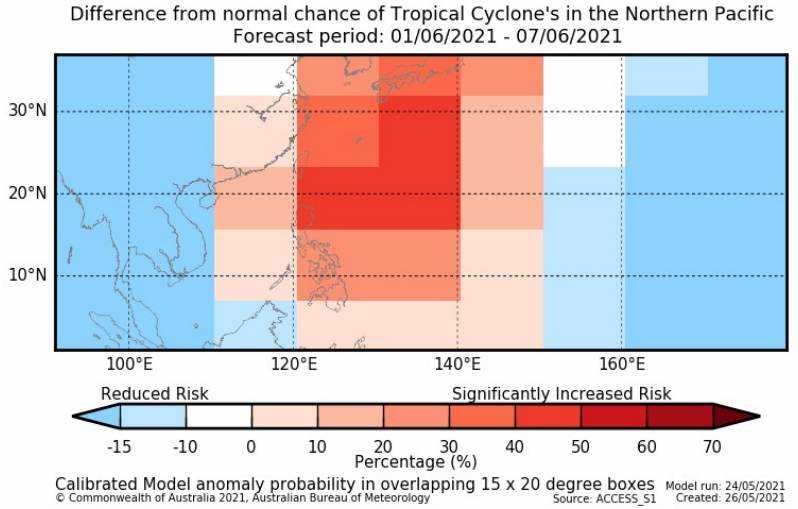

- Model calibrated using the ACCESS-S1 hindcast (1990-2012).
- Available for the southern hemisphere and northwest Pacific.
- Different from normal chance – anomaly – forecast that is different from the increased/decreased risk at different times of the year.
- Calibrated forecasts tend to perform better later on, weeks 3 and 4 (real time verification 2017/18)
- Reduces false alarms (raw model can be overconfident)
- Using the calibrated probabilities gives the best improvement in skill and reliability at the expense of sharpness (i.e. we lose the ability to forecast very high probability events).

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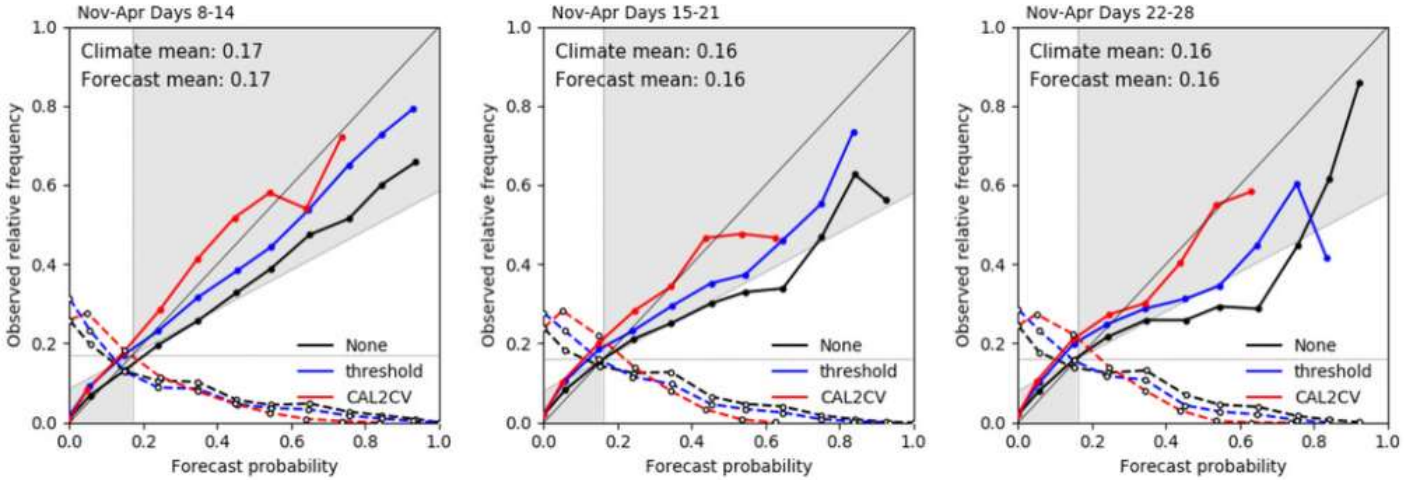
ACCESS-S1 CALIBRATED hindcast skill – Southern Hemisphere



- The hindcast is used to account for model biases
- Using the calibrated probabilities gives the best improvement in skill and reliability at the expense of sharpness (i.e. we lose the ability to forecast very high probability events).

SH	Days 4-7	Days 8-14	Days 15-21	Days 22-28
Raw	0.216	-0.042	-0.143	-0.185
w/ 14 m/s threshold	0.216	0.128	0.044	0.023
Calibrated	0.268	0.155	0.096	0.074

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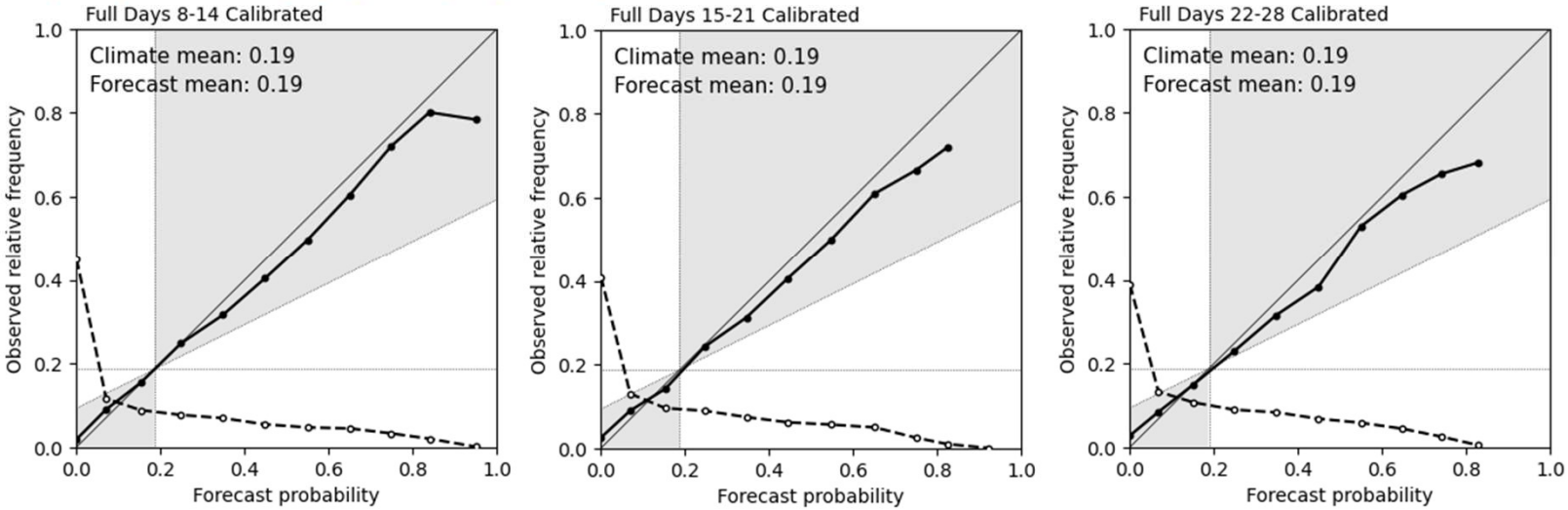
ACCESS-S1 CALIBRATED hindcast skill – North West Pacific



North west Pacific	Days 8-14	Days 15-21	Days 22-28
Raw (+ 14m/s threshold)	0.285	0.222	0.212
Calibrated	0.310	0.252	0.235

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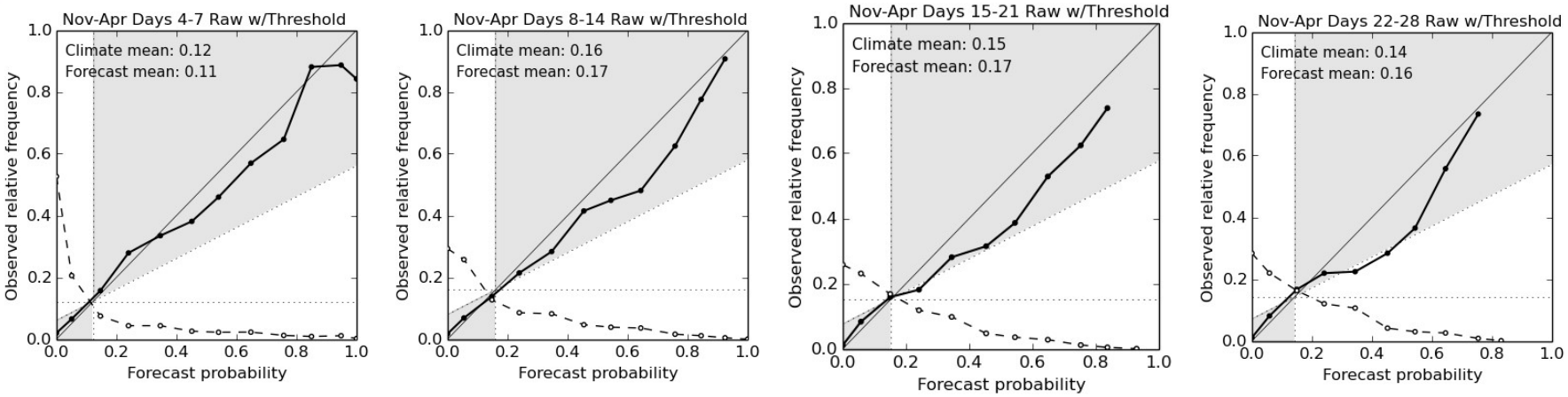
ACCESS-S1 forecast skill 2017/2018



- The forecast skill for the 2017-18 season was better than the hindcast skill (SH). This could be attributed to increased number of ensembles (33 in the operational forecasts vs. 11 in the hindcast)
- Use of ACCESS-G to provide the atmospheric control member in the operational forecast vs. ERA analysis in the hindcast
- Strong MJO events may have increased predictability of storm formation in 2017-18 (i.e. it might have been an easy season to forecast)

SH	Days 4-7	Days 8-14	Days 15-21	Days 22-28
Raw	0.221	0.089	-0.006	-0.060
w/ 14 m/s threshold	0.304	0.209	0.125	0.108
Calibrated	0.279	0.182	0.140	0.121

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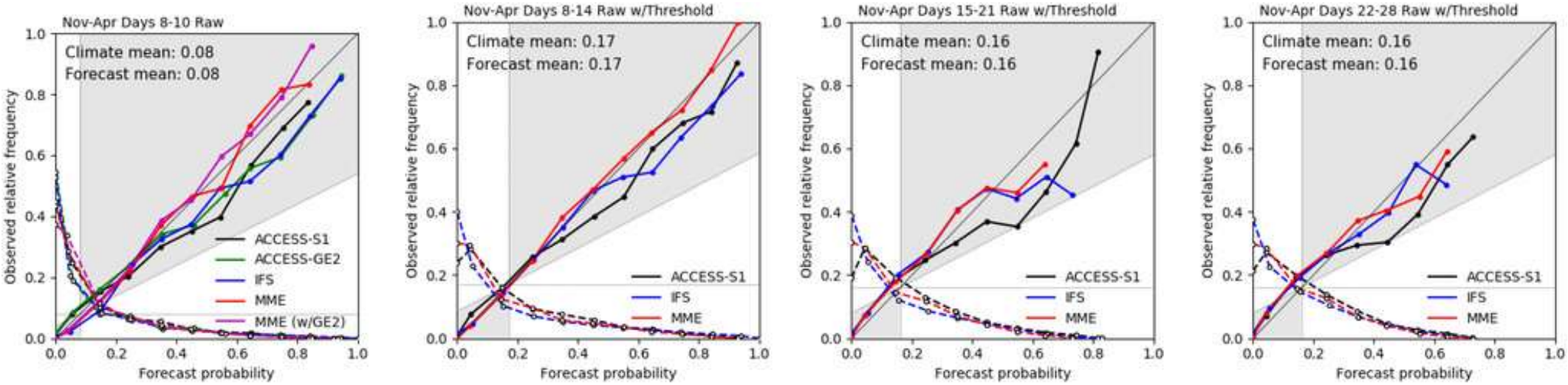
How about an MME



- IFS is more reliable at shorter lead times (higher resolution, more ensemble members (51), think of it as an extended NWP)
- ACCESS-S1 is more reliable at longer lead times
- MME is slightly more reliable at all lead times (large ensemble size: 84)

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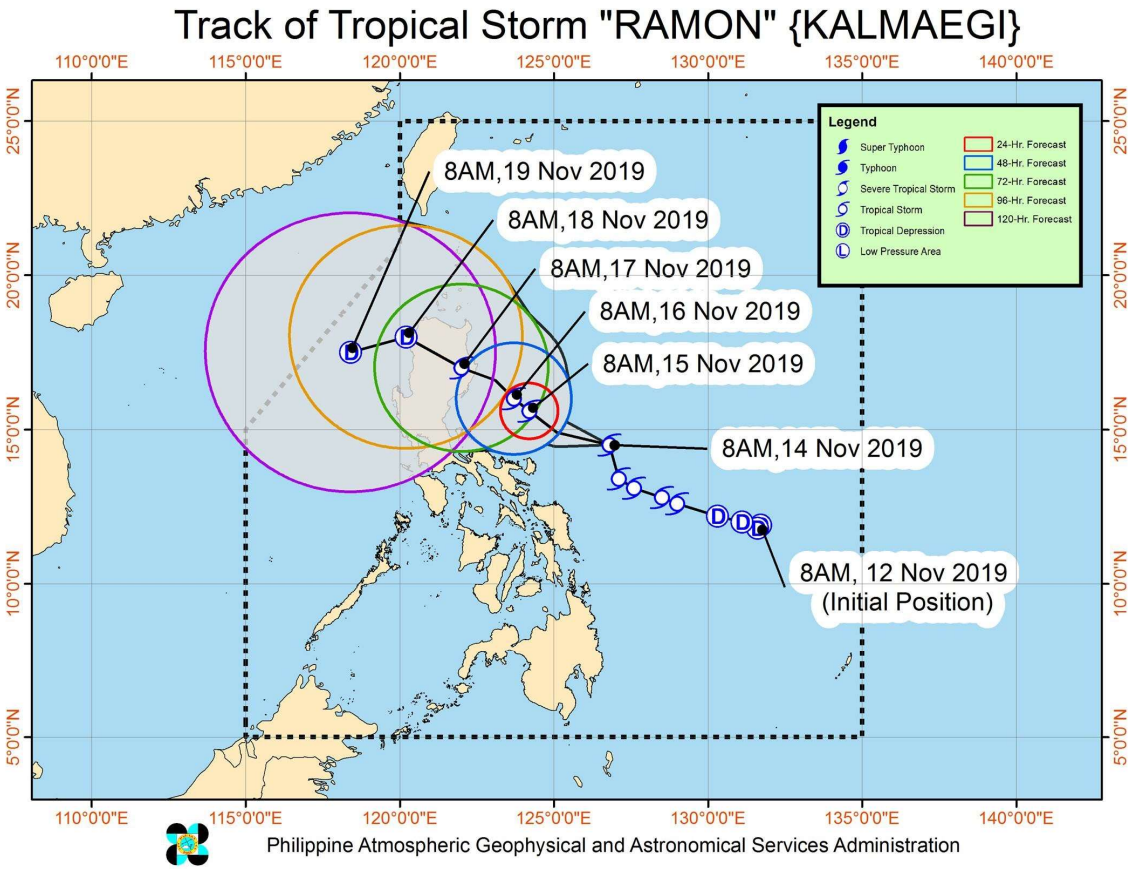
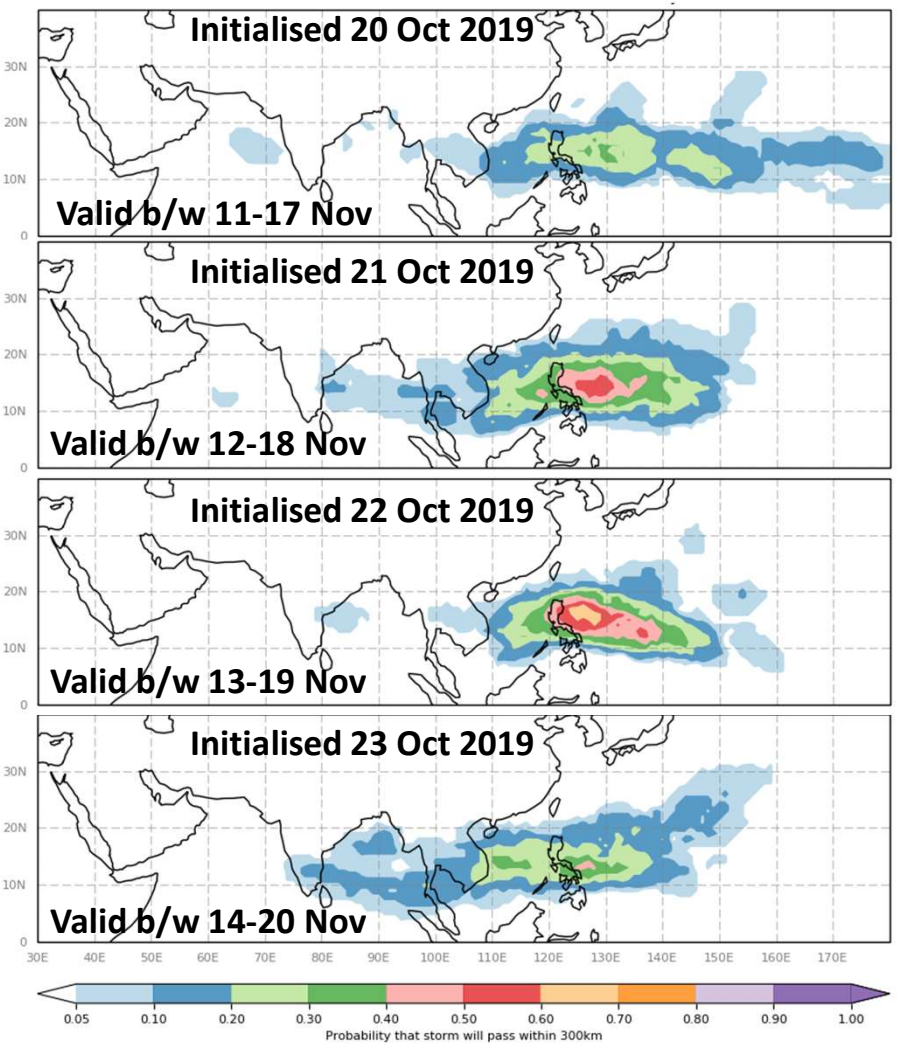
Tropical Storm Ramon (Kalmaegi) - 2019





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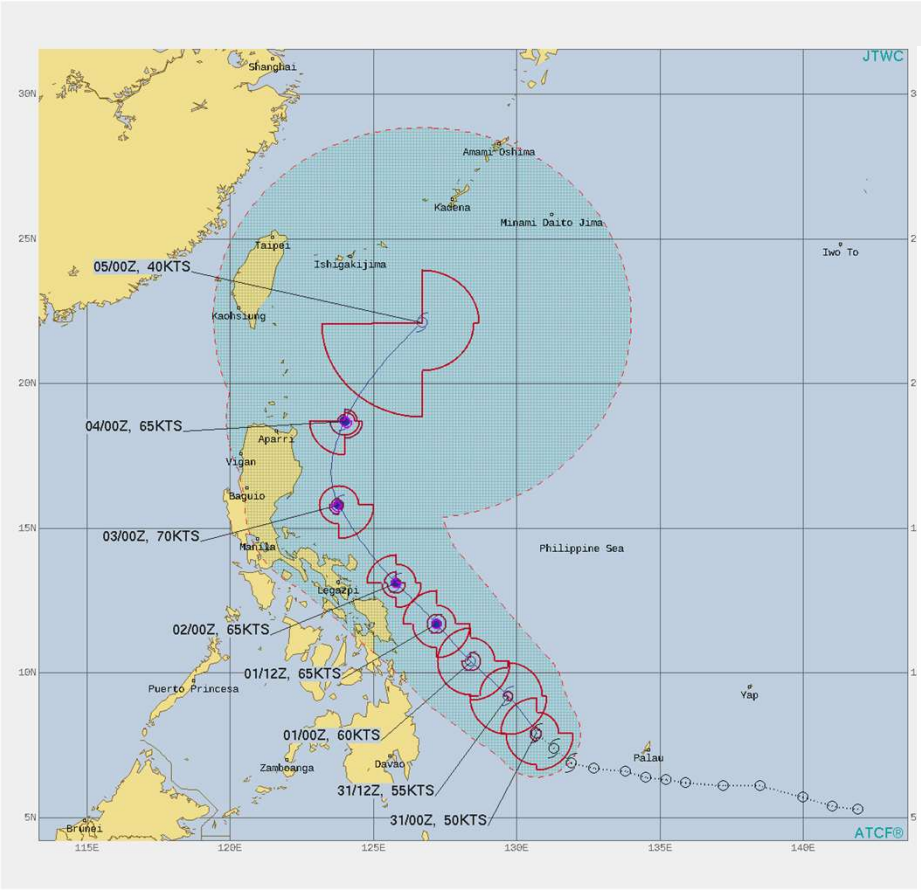
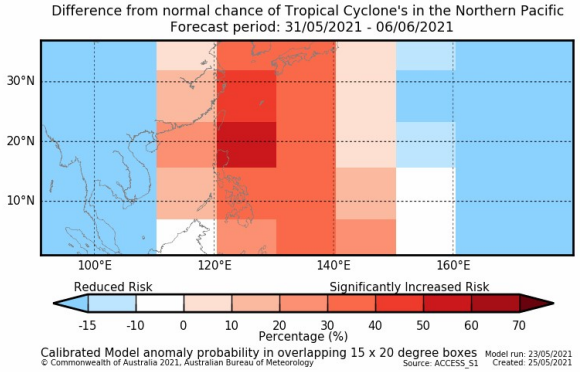
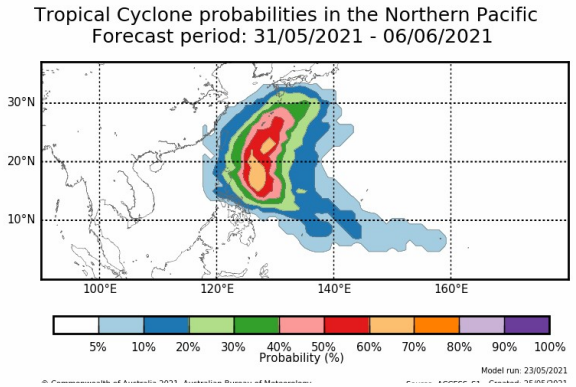
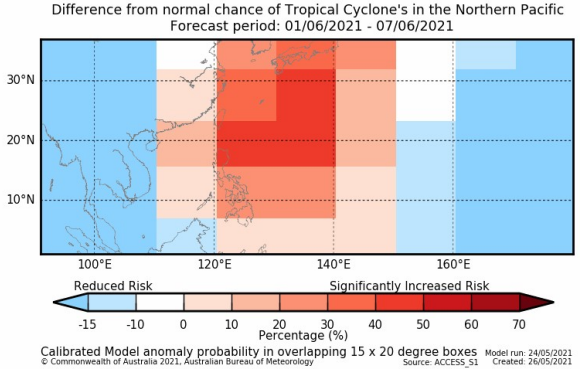
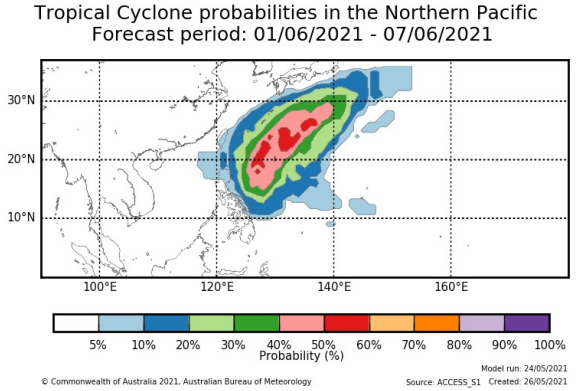
Tropical Storm Choi-wan (Dante) - 2021



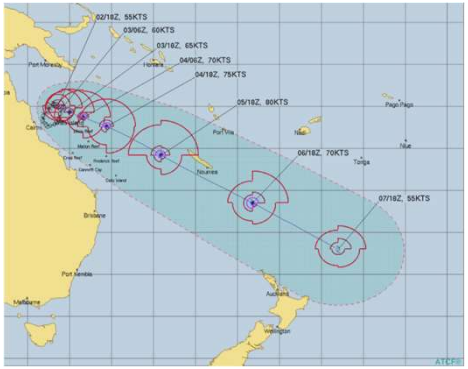




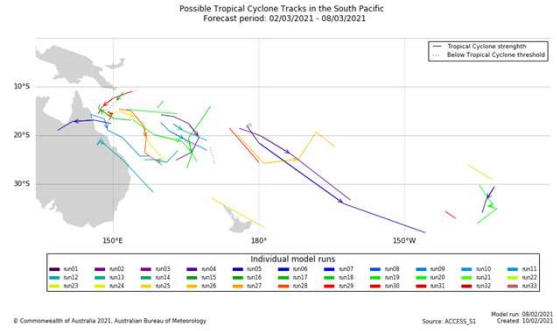




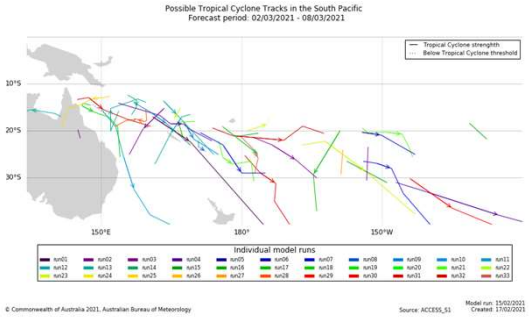
Tropical Cyclone Niran- 2021



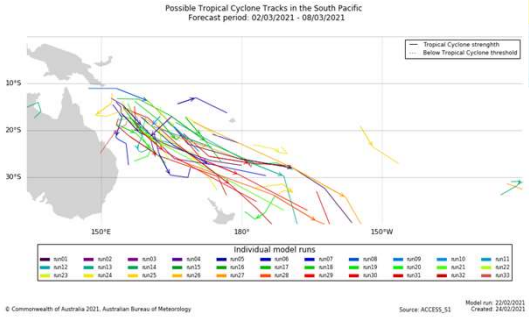
Forecast: 4 weeks out

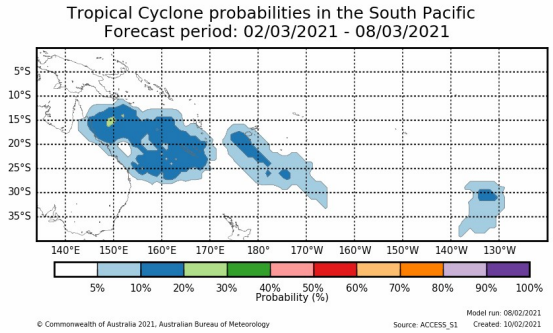


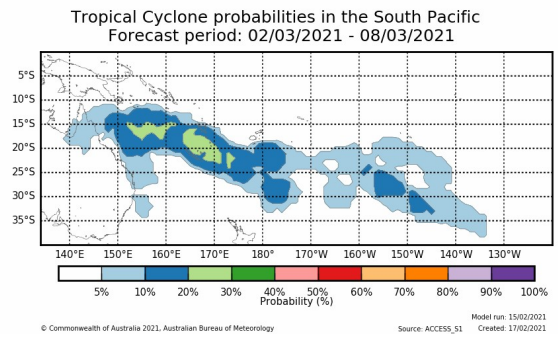
Forecast: 3 weeks out

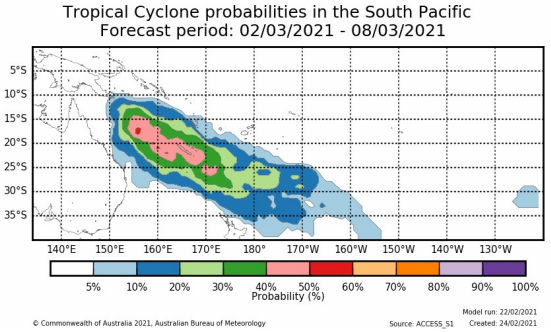


Forecast: 2 weeks out









- Ensemble members become consistent in location and direction with shorter lead times (note ensemble member forecasts are for demonstration purposes and not for public release)
- Probabilities increase with shorter lead times, probabilities tend to be smaller in the South Pacific than the north west Pacific region

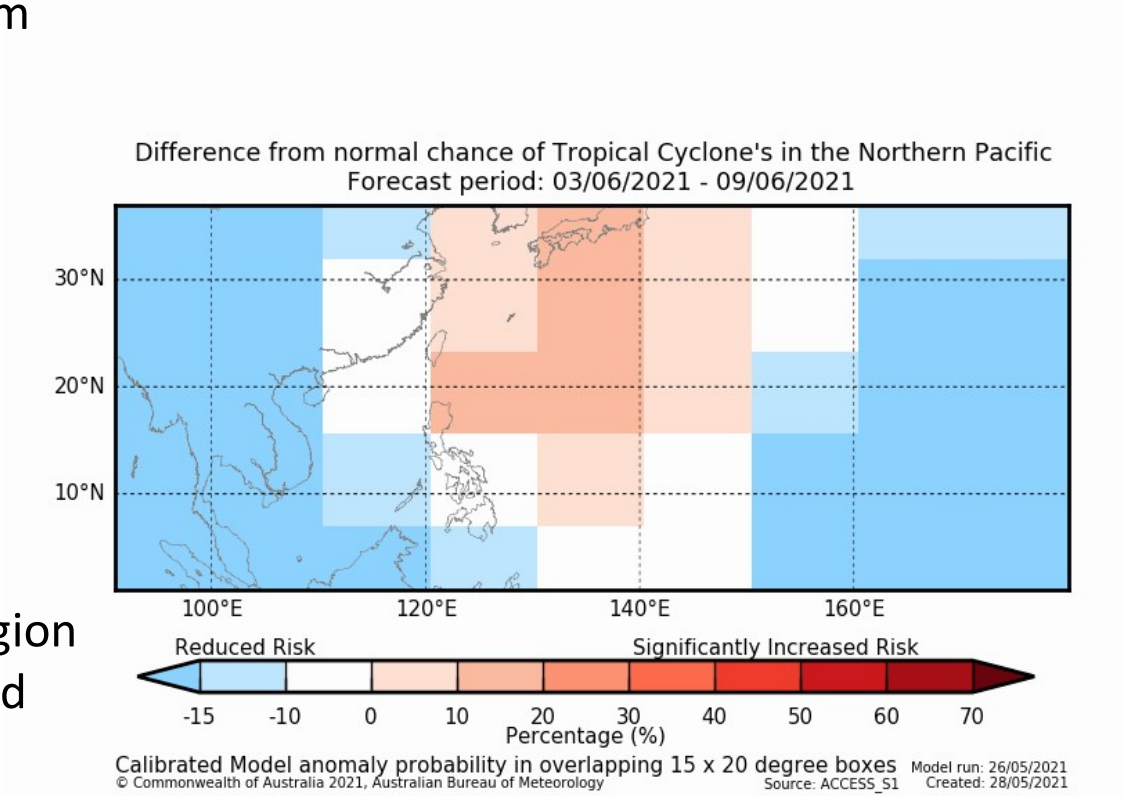
Climate and Oceans Support Program in the Pacific

Tropical Cyclone Outlooks GOTCHA'S

- A probabilistic forecast cannot predict the number of Cyclones within a particular week (or region)
- It's not a daily NWP forecast nor can you add the weekly forecasts to get to a month. Don't apply any fancy maths!
- Remember to always use your NWP TC forecast for the first week, it has better skill. ACCESS-S outlooks are not released to cover this first week, check when the model was run if you think you have a week 1 outlook because it will be out-of-date.
- Only use older ACCESS-S outlooks to be more confident about todays forecast, that is, are the probabilities the same as yesterday's in the same region? A new forecast makes the previous one obsolete.

Interpretation guidance for stakeholders

- Preference is to present the 'difference from normal chances' for stakeholders. This will reduce the false alarm rate.
- 10-30% - is an 'increased risk of tropical cyclone occurrence'
- 30% + - is a 'significantly increased risk of tropical cyclone occurrence'.
- Remember **an increased risk does not guarantee** a Tropical Cyclone will form
- More confidence in forecasts that show elevated risk over a number of days in a region
- More confidence in forecasts at shorter lead times, e.g. week2

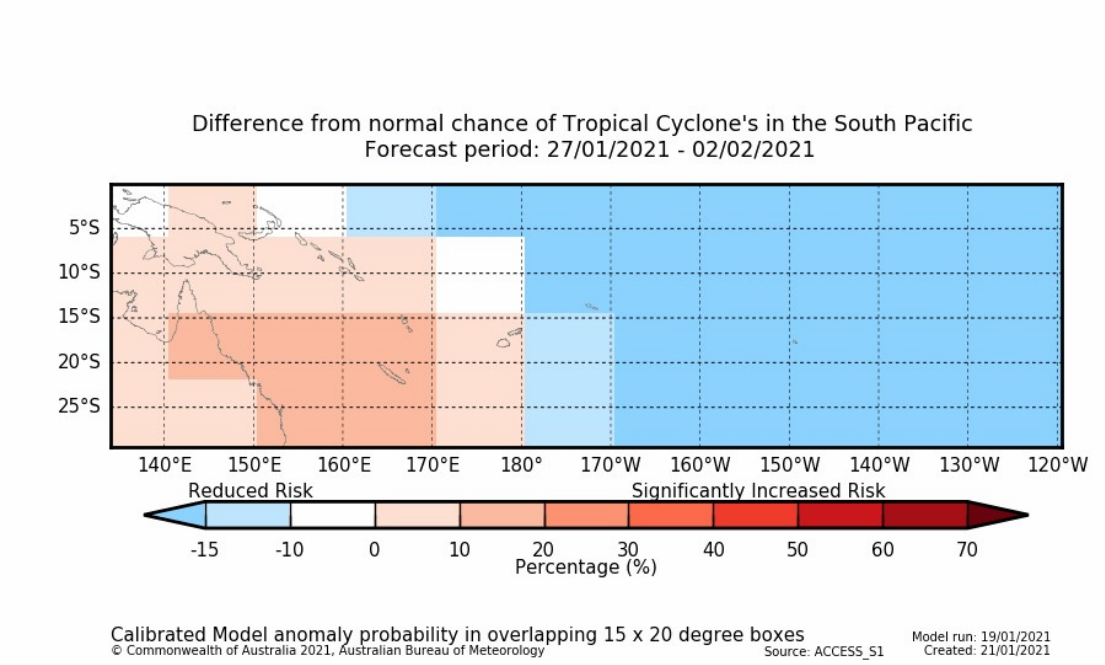


http://access-s.clide.cloud/files/guidance_documents/About_weekly_ACCESS-S_TC_forecasts_brief.pdf

Climate and Oceans Support Program in the Pacific

Scenario: 21st January 2021

It's January 21 and you see the below TC forecast. What do you do?

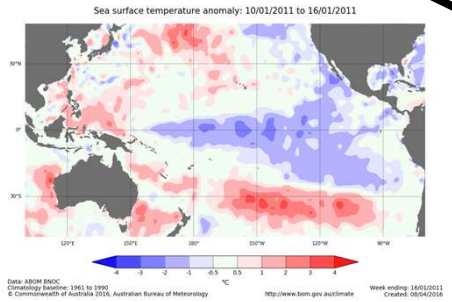


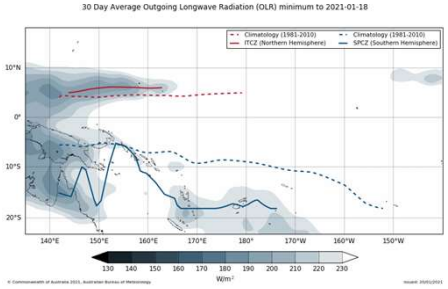
- There is significantly increased risk of TC occurrence in the western South Pacific.
- Have a look at the TC probability map and yesterday's forecast (are the forecasts consistent?)
- Evaluate the background climate, do observations suggest a TC risk?
- What do the other climate outlooks show, are they consistent with TC occurrence risk
- What could be the impacts?

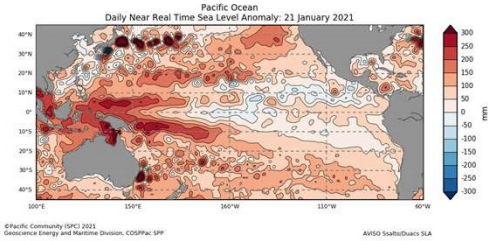
Scenario: 21st January 2021

Climate and Oceans Support Program in the Pacific

Observations



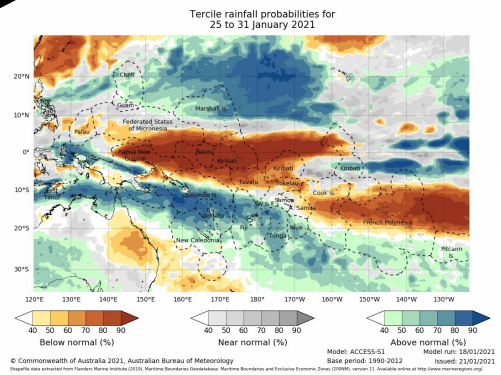


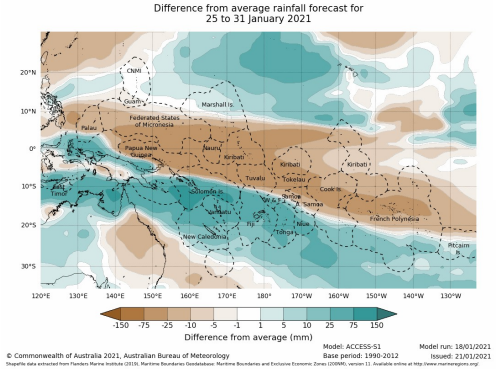


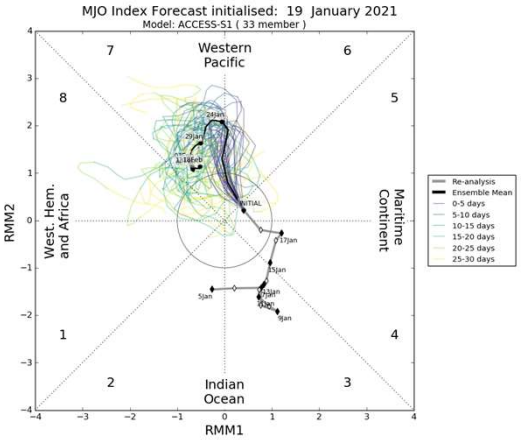
Impact risks to consider:

- Has there been more rainfall than usual in the last few weeks?
- Are water storages already full?
- Is there a risk of river or tidal flooding?

Forecasts



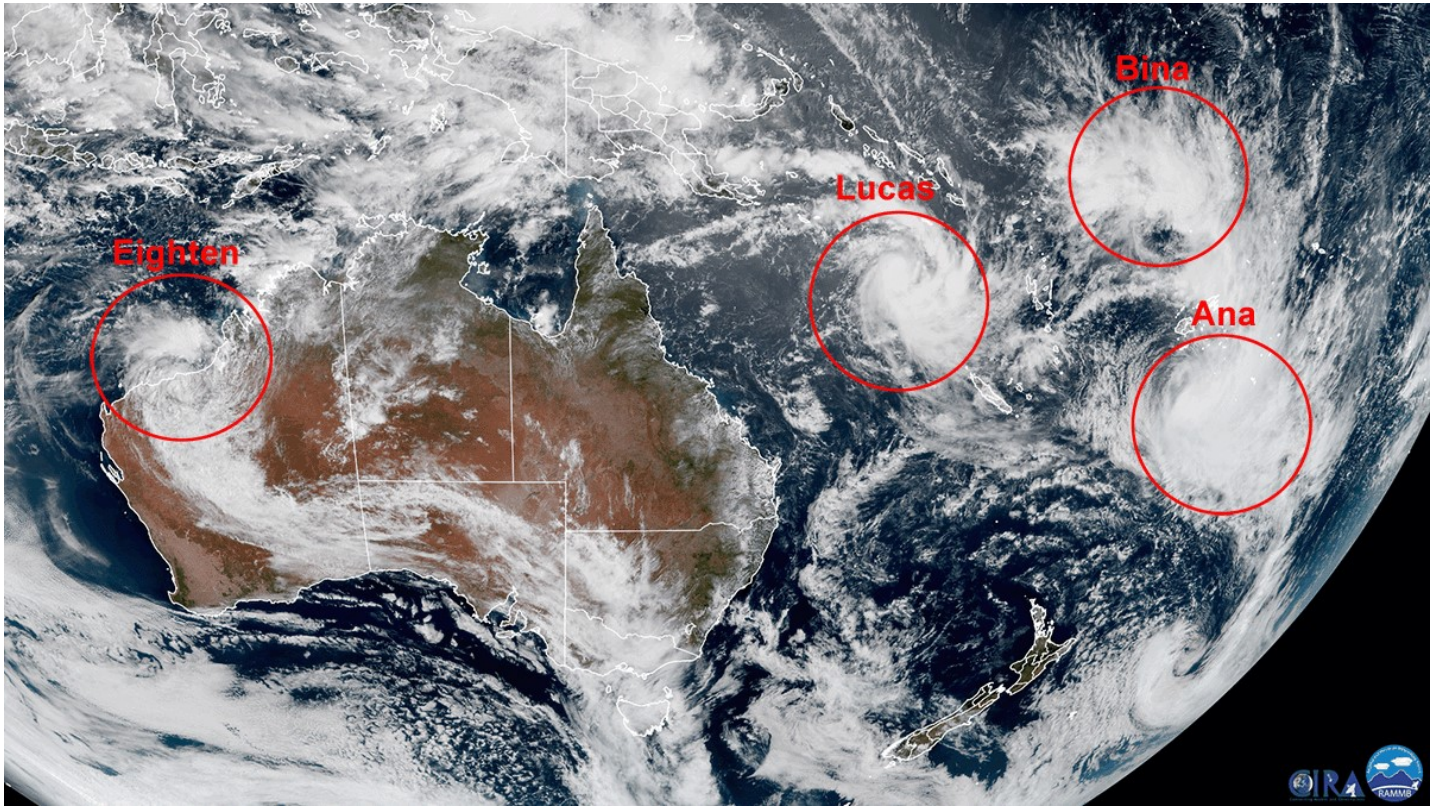




Climate forecasts available: Week 2 (25 – 31 January 2021)

Climate and Oceans Support Program in the Pacific

February 1 2021



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Conclusion

- Consider both probability and calibrated anomaly probability forecasts
- Monitor forecasts from previous days, confidence increases with persistence over time
- The model is in general overconfident, particularly in the South Pacific, it predicts more Tropical Cyclones than are observed.
- The false alarms can be improved by calibrating the forecasts (difference from normal outlooks), however we lose the ability to forecast very high probability events.
- Tropical Cyclone outlook skill is highest in Week 2 (and week1) of the forecast period
- Calibrated anomaly outlooks offer some skill in Weeks 3 and 4
- Use consistent terminology with stakeholders and see the guidance documentation for more information.
- Consider other aspects of the climate system and the forecasts, are the impacts from a cyclone particularly high, such as, is river flooding more likely due to catchments already being wet?