Draft report on weather conditions and forecast on the 10 10 2017 in Durban Harbour

Issued on

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INTRODUCTION

1. The purpose of this report is, in broad summary, as follows:

    1.1. To explain the basic methodologies involved in wind and weather forecasting, and the nature and extent of the limitations thereof.

    1.2. To report on the weather and wind conditions, which prevailed in Durban Harbor the 10 10 2017.

WIND AND WEATHER FORECASTING

Introduction

2. Wind forecasting is like weather forecasting. It is a prediction of what the wind field will be like in an hour, tomorrow, or in a few days.

3. Weather and wind forecasting are active research fields, and the best forecasts are made by the national weather services.

4. The South African Weather Service is the only authority for providing and distribution of extreme weather and wind forecast.

5. Even the best national weather service cannot provide all the information required for an accurate assessment of all risks associated with extreme events. For instance, strong wind was forecasted for all regions of Kwazulu-Natal during the relevant period. 'Strong wind' for forecasting purposes means anything above 80 km/h, while on the day of the Great Storm mean wind speeds of 125 km/h and wind gust of 175 km/h were recorded in Durban Harbor.

6. Although progress has been made in recent years in wind forecasting, and in providing tailor-made weather forecasts for end users, there are still many uncertainties, and important information is still not readily available to the end user, for instance the exact wind speed and direction at a specific time in a specific location and height.

7. The accurate forecasting of extreme weather, such as tornadoes, tropical cyclones, storm surges, floods and strong wind associated with severe thunderstorms is, for example, still very challenging, and the subject of research worldwide.

8. Radars provide real time information used to extrapolate the trajectory of severe thunderstorms.

9. As a practical example, Radar is an essential tool to help airport authorities to forecast strong winds associated with thunderstorms, as numerical wind forecast is not accurate enough at the scale of an airport.

10. The accuracy which radar information provides is essential for operational decision making, and without this information airports would be closed more often for safety reasons. This is because severe thunderstorms are otherwise forecasted for a region, but do not occur at all locations of said region and for the entirety of the period relevant to the forecast.

Forecasting methodologies

11. There are several different methods that can be used to create a forecast. The method a forecaster chooses depends upon the experience of the forecaster, the amount of information available to him or her, the level of difficulty that the forecast situation presents, and the degree of accuracy or confidence needed in the forecast.

12. Another challenge is the timely dissemination of the forecast.

13. Numerical weather prediction (***NWP***) uses the power of computers to produce a forecast. Complex computer programs, also known as forecast models, run on supercomputers, provide predictions on many atmospheric variables such as temperature, pressure, wind, and rainfall.

14. The amount of computer time and power necessary to solve the equations limit the spatial and time resolution of the forecasting models.

15. Forecasted wind and weather properties are calculated for a discrete point location on a grid (for example 50 km by 50 km or 100km by 100km). The atmospheric models divide the atmosphere, oceans and land into a 3-

dimensional grid system shown below. The equations are then calculated for each cell in the grid and at each time step (for instance every 3 hours).

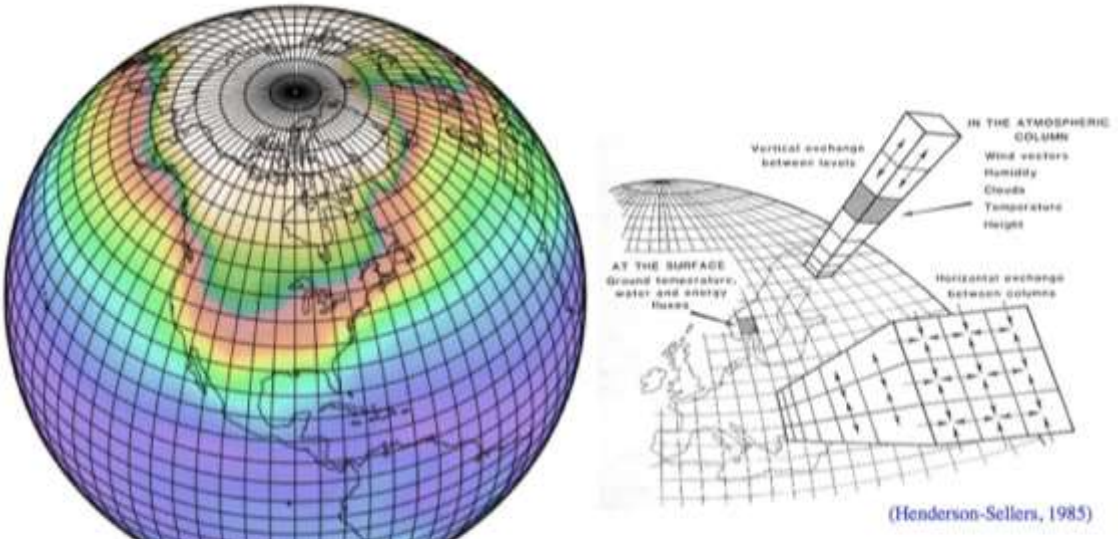


Figure 1: typical 3-dimentional grid use for numerical weather forecasting in horizontal and vertical

16. Contrary to what one might expect, a higher resolution of the grid (for instance 50 km by 50 km as opposed to 100 km by 100 km) will not necessarily result in the calculated wind being more accurate. This is because limitations in the equations used for forecasting cannot consider all phenomena existing in the real world.

17. Although a chart for the estimated conditions would probably show a difference in the forecasted wind conditions, the accuracy of the results is questionable due to limitations in the spatial and time resolution of the model, the equations

used to simulate the weather and the algorithm used to solve the equations (because the equations cannot be solved directly, one needs to use an algorithm to approximate those equations).

18. Surface wind forecasts are meant to represent wind speeds at the standard height of 10 metres above surface. Wind speed increases with height above the ground or sea surface and follows a logarithmic profile as a function of height above the sea surface. Wind gusts can be 50% stronger than the average wind speed.

19. Weather forecasting involves the consideration and analysis of a combination of computer model simulations, observations from weather buoys or satellites, remote sensing, human intervention and local knowledge, wind climatology, trends and patterns. By using these sources, reasonably accurate weather forecasts can be made up a few days in advance, although limitations exist in extreme rainfall and wind forecasts, which may make them less accurate. Comparing weather forecasts and the conditions experienced are key to improving forecasts, and the reason of the improvement in weather forecasting over the last 20 years.

20. The accuracy of a forecast (i.e. of the model output) depends upon the parameterisation of the model (i.e. the way physical phenomena are described by a set of mathematical equations), the extent and quality of the input data, and its assimilation into the model (for instance wind speed and direction).

21. Because forecasted wind and weather properties are calculated by computer, they will be different to the actual wind which would be observed by a human

being at the relevant location, time and height. The forecast properties usually represent a 3-hour average, centred on the time stamp (the time of the forecast), and are a lot smoother than reality.

22. As a result, one cannot expect to have an exact match between an observation at a certain time and position, and a weather forecast for that time and position. The timing of the forecasted event is not accurate enough to enable such a comparison. By way of analogy, it amounts to comparing the average speed of a car over a three-hour journey to the instantaneous speed of that car at any time during the journey. One could not determine the accuracy of the average speed calculation by reference to the instantaneous speed. If one was to undertake such a comparison between the forecasted parameters and those observed at a time, one would have to compare the forecast to an average of about three hours' worth of observations around the relevant time.

23. Furthermore, the longer the forecast period, the less accurate the forecast. A two-day forecast is less accurate than a one-day forecast. Two to three-day rain forecasts are quite accurate in South Africa. The forecasting of extreme weather (such as the conditions experienced on 10 October 2017) is always problematic.

24. The SAWS forecasts provided are generic, both in the sense that they cover large areas, for instance KwaZulu Natal, and a 6 to 24 hours period.

25. In general, at a weather forecasting service a team of forecasters examine how the features predicted by the computer will interact to produce the day's

weather, also, where possible, using satellite remote sensing images and local observations.

26. To produce a weather and wind forecast, computer models are programmed to solve mathematical equations (Navier Stokes equations) which describe the flow of air in the atmosphere, including the development and evolution of storms. The equations describe changes in wind, temperature, pressure, water vapour amount, cloud water amount, etc. at selected points in the atmosphere. For example, a modeller might start solving the equations at some time, T, calculating values at the selected points 10 seconds later. Using these new values, the solution can be computed at time T + 20 seconds. This process is often continued for hours as storms grow and decay within the modelled atmosphere.

Errors and uncertainties in wind forecasting.

27. The NWP method has limitations in that the equations used by the models to simulate the atmosphere are not precise and cannot be solved directly so the results is an approximation. This leads to inaccuracies in the forecasts. The extent of the inaccuracies increases as a function of lead time. As set out above, the models depend on observations, and will be less accurate when there are less observations available for the area in respect of which the forecast is being generated. There are few weather observations from South Africa and in the Southern Ocean which are assimilated by the numerical models used to produce the wind field. If the initial state is not completely known, the computer's prediction of how that initial state will evolve will be less

accurate. There are also not many observations to validate those models and improve them.

28. A model run a second time will give a different result than the first time. This is because the equations to be solved cannot be solved directly but can only be approximated by complex algorithms.

Glossary of weather terms

29. The following definitions are based on and copied from the American Meteorological society glossary, which is the world authority in weather, climate and Ocean related science definition. Included in italics are the South African Weather Service definitions.

30. **Low pressure system:** (Sometimes called depression.) In meteorology, an "area of low pressure," referring to a minimum of atmospheric pressure in two dimensions (closed isobars) on a constant-height chart or a minimum of height (closed contours) on a constant-pressure chart. A low-pressure system is, on a synoptic chart, always associated with cyclonic circulation. *Cold Front and Cut off low are typical South African weather system.*

31. **Thunderstorm:** In general, a local storm, invariably produced by a cumulonimbus cloud and always accompanied by lightning and thunder, usually with strong gusts of wind, heavy rain, and sometimes with hail. It is usually of short duration, seldom over two hours for any one storm. A thunderstorm is a consequence of atmospheric instability and constitutes, loosely, an overturning of air layers to achieve a more stable density stratification. A strong convective updraft is a distinguishing feature of this

storm in its early phases. A strong downdraft in a column of precipitation marks its dissipating stages.

32. **Squall line:** A line of active deep moist convection frequently associated with thunder, either continuous or with breaks, including contiguous precipitation areas. A strong wind characterized by a sudden onset, a duration of the order of minutes, and then a rather sudden decrease in speed. In nautical use, a severe local storm considered, that is, winds and cloud mass and (if any) precipitation, thunder and lightning.
33. **Cut-off low:** A cold low that has grown out of a trough and become displaced out of the basic westerly current and lies equatorward of this current.
34. **Cold low:** At a given level in the atmosphere, any low that is generally characterized by colder air near its center than around its periphery; the opposite of a warm low. A significant case of a cold low is that of a cut-off low, characterized by a completely isolated pool of cold air within its vortex.

Wind and atmospheric pressure Condition on the 10 of October 2017

35. The analysis of the 4 Durban Harbor anemometers plus the Bluff Harbor Port Control 2, Port Shepstone and the Tugela anemometer which form part of the Integrated Port Operation Support System (IPOSS) provide useful information on what happened on 10 of October 2017 and how often such wind speed was recorded at the IPOSS establishment 6 years ago by the CSIR (Chapter 2 and 3).
36. Additionally, atmospheric pressure is recorded at the Harbor Port Control 2 and presented on Figure 1.
37. Figure 1 to 7 present (top figure): 5-minute mean wind speed (black) and maximum wind gust during that 5-minute period (blue). Bottom figure: wind

direction on 10 10 2017 (blue) every 5-minutes for the 4 Durban Harbour anemometers, Port Shepstone and Tugela.

38. The wind accelerated very quickly at around 09:30 am on 10 October 2017 and reached very high wind speeds with maximum at 10:00 am on 10 October 2017 decreasing gradually within the next hour quickly to the same speed. Strong wind was experienced from a westerly direction to a Southerly direction on the 10 October 2017.
39. All Durban Harbor anemometers have recorded their 6-years maximum average wind of up to 125 km/h and maximum gust of up to 175 km/h the day of the Great Storm on the 10 of October 2017 at around 10 am since inception of the Integrated Port Operation Support System. The Harbor Control 2 anemometer DB03 at the Bluff recorded its maximum wind speed and minimum atmospheric pressure at 10:40 a bit later.
40. For instance, for Port Control 2, looking at the 10 maximum values recorded since 2013, the four top maximum wind values (156 km/h, 154 km/h, 140 km/h, 117.4 km/h) occurred on the 10 10 10. 117 km/h, 109 km/h and 105 were recorded on 16 9 2017. 112 km/h was recorded on 11 10 2014. 104 km/h was recorded on 10 10 2019 and 100 km/h was recorded on 25 3 2018. Those were the 5 top days
41. Minimum pressure was 1000 hPa on the 10 10 2019 at 10:40 at the Harbor Port Control 2. This was not abnormal. Pressure of around 1000 hPa were recorded about 1200 time between 2013 and 2017.
42. The pressure at 09:40, 1005 Hpa, just before the maximum wind sped experienced at the Harbor gave no indication of an upcoming extreme event.
43. At 10:00 the drop of 2 hPa in 20 minutes is not abnormal.

44. Pressure dropped 5 hPa in one hour from 0940 to 10:00 UTC on the 10 10 2017 which is not abnormal
45. Since the main system was a cut off low, it is not abnormal to have the pressure not below 1000 hPa during the related storm.
46. Pressure of 1000 hPa and below are symptomatic of low-pressure system but wind speed and pressure are not proportional. It is the horizontal pressure gradient that matters, and this only be calculated from weather forecast output. Mean atmospheric pressure for the Harbor Control 2 station is 1017 hPa. Maximum is 1039 hPa and minimum is 989 hPa. Pressure below 1000 hPa were recorded 326 time between 2013 and 2017.
47. Pressure during the 5 days that experienced the strongest wind at the time of the highest wind occurrence reported above were 1000 hPa on 10 10 2017; 1015 hPa on 16 9 2017; 1000 hPa on 11 10 2014; 1001 hPa on 10 10 2015 with a minimum of 992 hPa that day four hour before the occurrence of maximum wind speed that day and 1008 hPa on 25 3 2018.
48. Difference between anemometer values in speed and direction can be accounted by different heights of measurements, distortion of the flow by building, vessel and orography. However, timing of events and change in direction and speed as a function is consistent between the Harbor's anemometers.
49. It is not possible to extrapolate or infer the exact wind speed and wind speed at the location of each pier or each vessel due to the absence of measurements there, but the anemometers of the Durban Harbour provide valuable data on what happens at the piers.

50. The anemometer at Port Shepstone (30˚44’31.40’’S Latitude and 30˚27’31.66’’E Longitude) and Tugela River (29˚13’21.06’’S Latitude and 31˚30’15.35’’E Longitude did not record their maximum hourly wind and gust on the 10 of October 2017.
51. These high values indicate wind speed associated to a squall line, or a severe thunderstorm or even a tornado. Such wind speeds are also recorded for tropical cyclone.
52. It is not possible to forecast the exact location or path of severe thunderstorm, tornadoes, squall lines of such extreme events or their occurrence at the scale of a harbour.
53. The absence of radar used by the SAWS would have prevented the SAWS from following that squall line or severe thunderstorm in real time as well as extrapolating its trajectory which is the best a forecaster can do for such extreme event. The Umhlanga (Durban) S-Band radar was down on the 10th of October 2017 due to a faulty ‘Azimuth encoder’. This was an intermittent fault, which was acknowledged on 6 October 2017 and repaired on 20 October 2017.

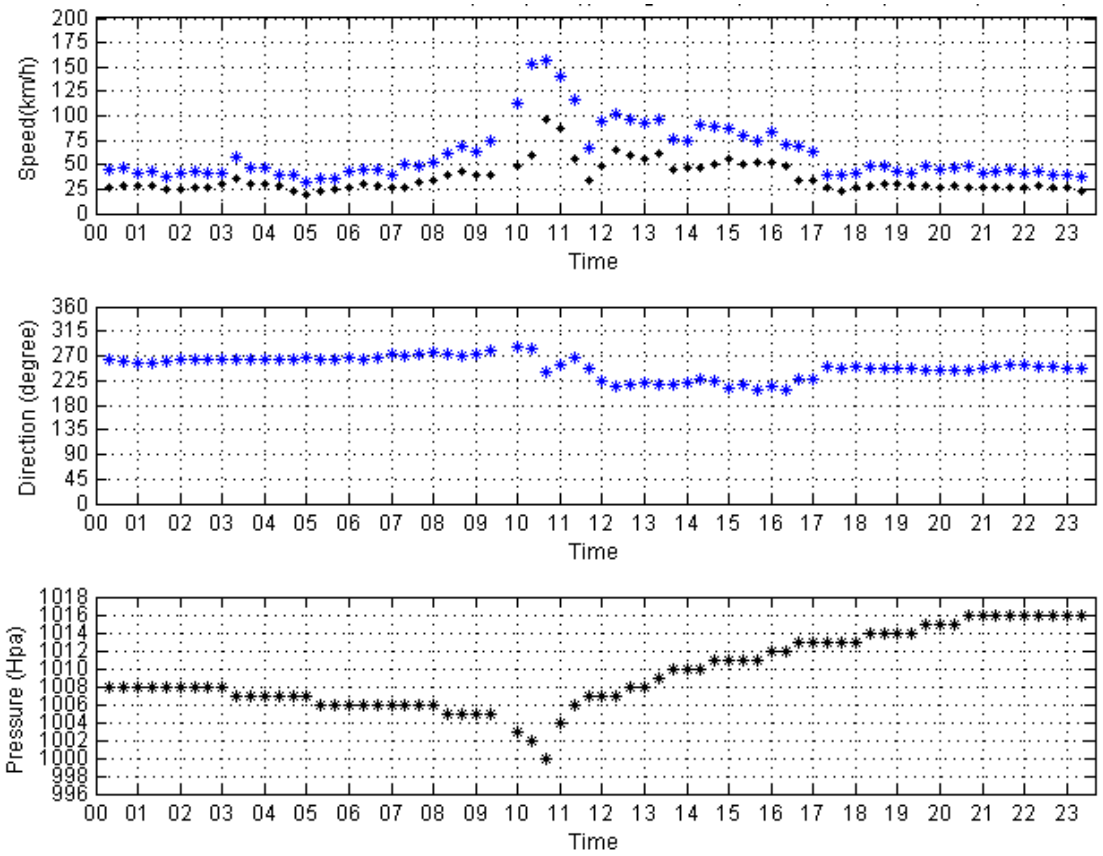


Figure 1: Top: 20-minute mean wind speed (black) and maximum wind gust (blue). Middle: wind direction. Bottom atmospheric pressure in hPa (black) on 10 10 2017 at DB03 Windnet Bluff Harbor Port CONTROL 2.

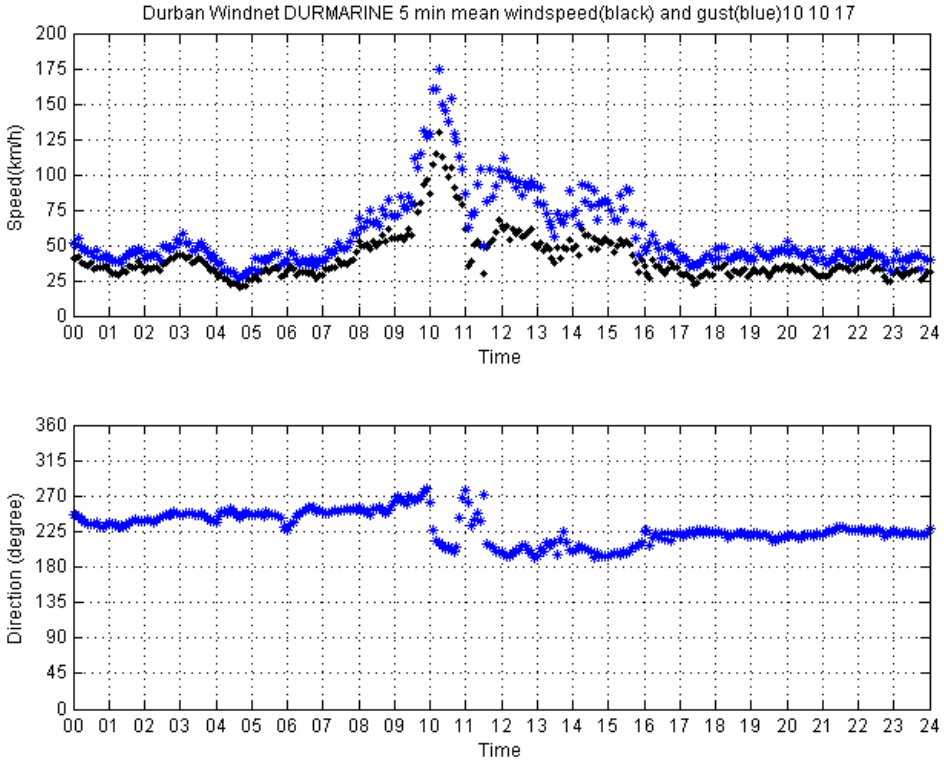


Figure 2: Top: 5-minute mean wind speed(black) and maximum wind gust(blue). Bottom: wind direction on 10 10 2017 at D101 Windnet Durmarine Building, Durban Harbor.

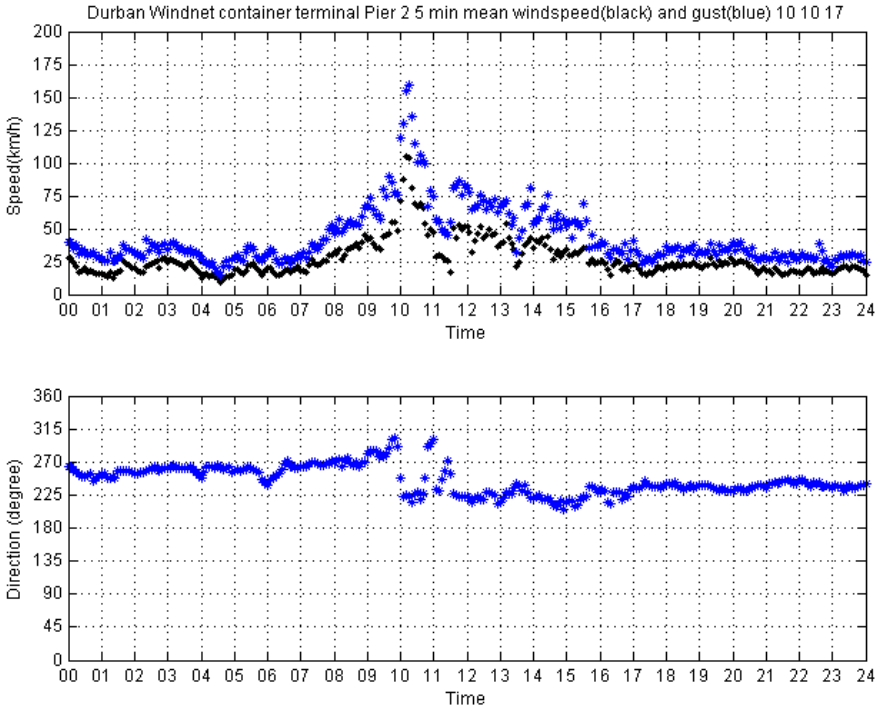


Figure 3. Top: 5-minute mean wind speed (black) and maximum wind gust (blue). Bottom: wind direction on 10 10 2017 at D201 Windnet Container terminal PIER 2, Durban Harbor.

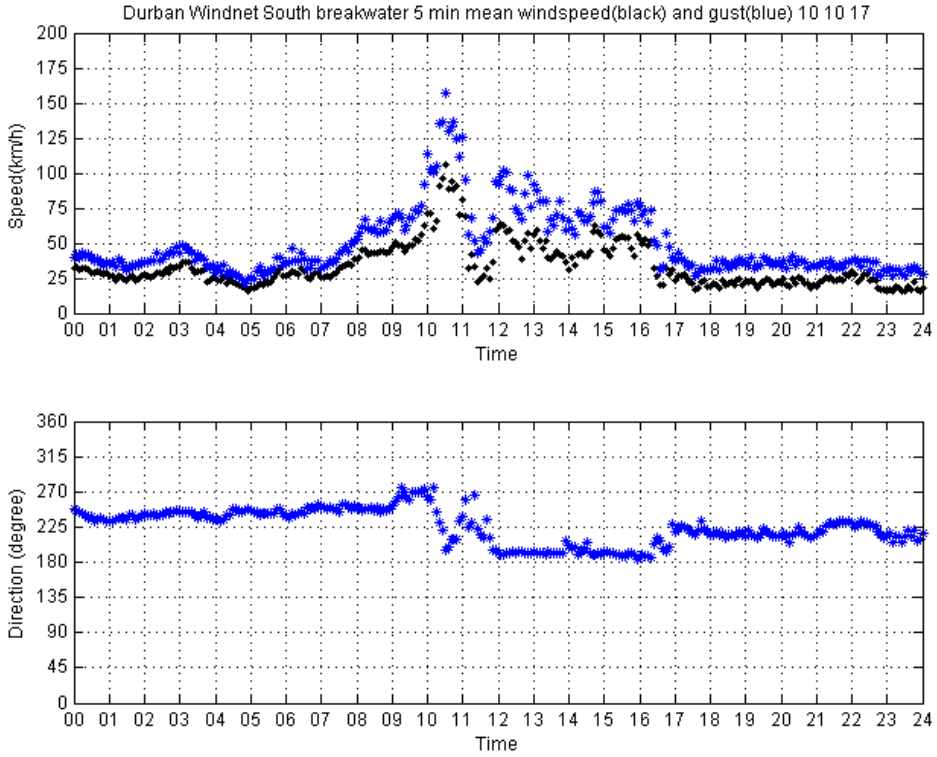


Figure 4. Top: 5-minute mean wind speed(black) and maximum wind(blue) gust. Bottom: wind direction on 10 10 2017 at D401 Windnet South Breakwater, Durban Harbor.

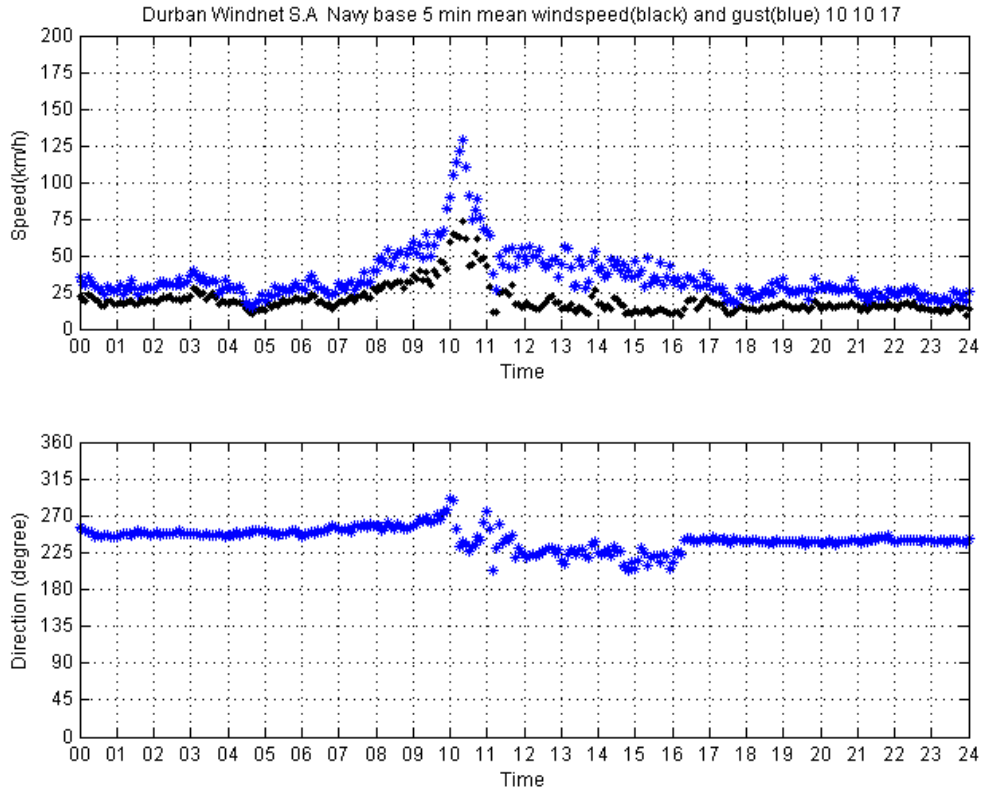


Figure 5. Top: 5-minute mean wind speed (black) and maximum wind gust (blue). Bottom: wind direction on 10 10 2017 at D301 Windnet **Navy Base, Durban Harbor**

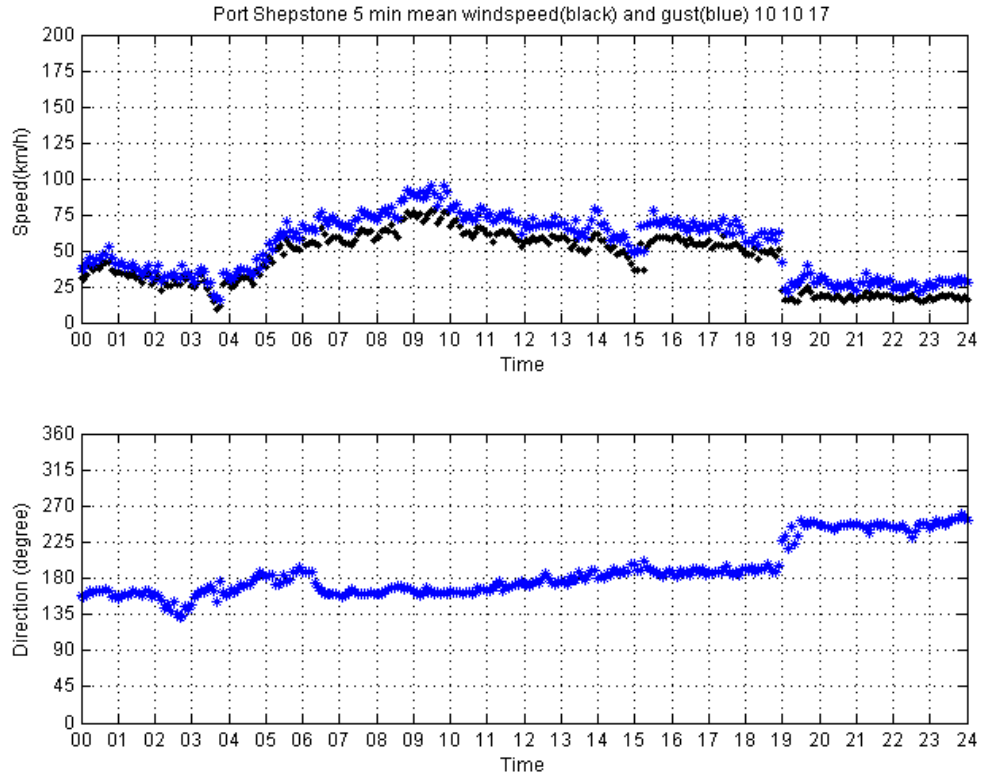


Figure 6. Top: 5-minute mean wind speed (black) and maximum wind gust (blue). Bottom: wind direction on 10 10 2017 at D501 Windnet Port Shepstone.

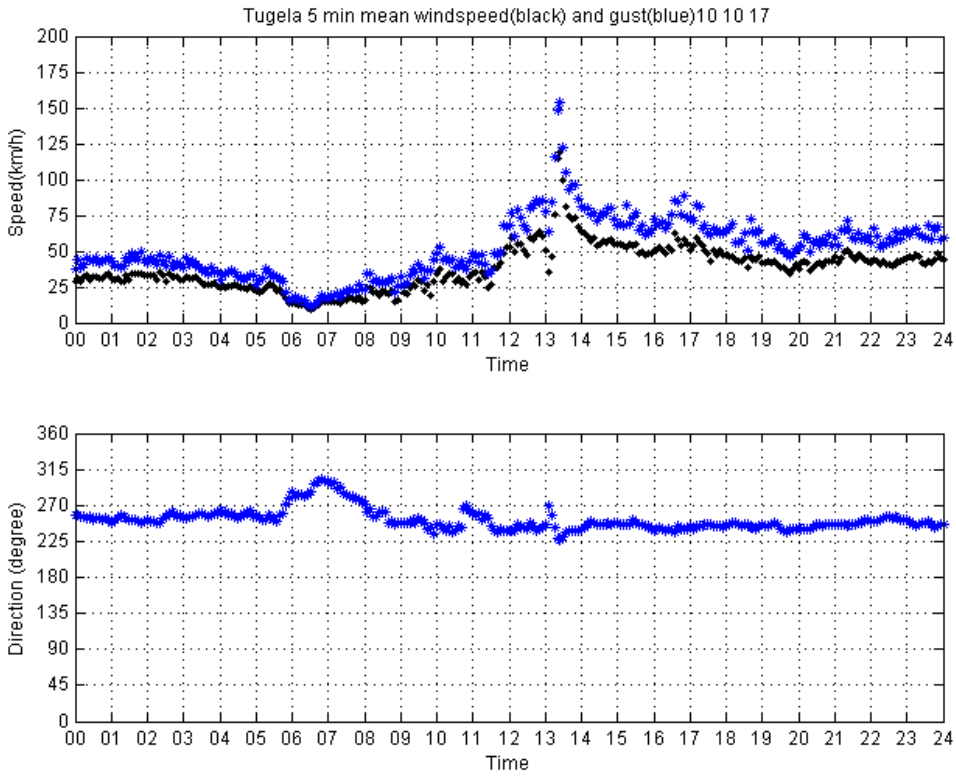


Figure 7. Top: 5-minute mean wind speed (black) and maximum wind gust (blue). Bottom: wind direction on 10 10 2017 at D601 Windnet Tugela Rivermouth lighthouse.

Climatology of wind speed, wind gust and wind direction

54. The historical record for the 4 Harbor anemometers and Port Shepstone and Tugela consists of hourly mean, maximum gust speed and time of maximum gust except for the Bluff Port Control and Tugela anemometers that was provided as 20-minute average and maximum gust speed during that time with time of maximum gust while from February 2013 to August 2018.

55. As a result, 0.002 % of occurrence of wind events presented in the climatology below represent roughly one hourly record for the 4 Harbor anemometers and Port Shepstone and 0.001 % represent two 20-minutes average records for Tugela and Bluff Port Control.

56. We remind that the 10 of October 2017 data record consists of 5 minutes mean wind speed and maximum gust of the last 5 minutes except for Bluff Port Control that is provided 20-minute average and maximum gust during that period.
57. As a result, the maximum average wind speed for one hours is expected to be lower than a 5-minutes average or a 20-minutes average maximum. However maximum wind gust is the same. For instance, if the wind goes from 10 km per hour to 22 km/h within one hour regularly, increasing 1 km/h every 5 minutes, the mean hourly wind speed will be 16 km/h while the maximum 5-minutes average will be 21.5 km/h and the maximum 20 minutes average will be 20 km/h during that one-hour period. This consideration helps to understand difference in maximum between maximum recorded on the 10 of October 2017 and maximum of the climatology.
58. The climatology of wind speed and direction reflect such difference in averaging but outline the storm of the 10 10 2017 as an outlier in the distribution of speed and wind and direction presented in figure 8 to 21.
59. The 10 October wind speed is seen in the maximum of the climatology as the maximum wind speed for the 4 Harbor's anemometers and appears as an outlier in the climatology of the distribution of wind speed and direction for hourly average wind speed and maximum gust shown below.
60. In general, maximum average or gust in the Durban hours occurs in a variety of direction depending on location (South, South West, West-South-West and West)
61. Other wind direction that leads to strong wind also occurs from the North East.

Hourly wind speed climatology

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-11.25	1.383	0.746	1.208	0.737	0.588	0.585	0.612	0.610	0.724	0.726	0.812	1.606	1.882	1.351	1.657	2.335	17.561
11.25-22.5	2.357	2.649	4.182	1.506	0.940	0.657	0.755	1.128	1.814	2.722	4.741	8.752	4.945	1.143	0.628	0.750	39.669
22.5-33.75	1.077	3.216	5.999	1.242	0.242	0.149	0.144	0.447	1.368	3.148	5.358	1.729	0.245	0.029	0.013	0.028	24.434
33.75-45	0.227	1.462	5.382	0.757	0.059	0.032	0.028	0.095	0.619	1.705	1.614	0.137	0.022	0.002	0.007	0.003	12.152
45-56.25	0.014	0.535	2.924	0.397	0.048	0.004	0.004	0.015	0.146	0.529	0.223	0.005	0.001	0.001	0.002	0.003	4.851
56.25-67.5	0.007	0.133	0.723	0.110	0.007	0.001	0.004		0.001	0.038	0.024			0.001	0.001		1.050
67.5-78.75		0.026	0.134	0.017	0.002	0.001	0.001			0.004	0.001						0.187
78.75-90		0.001	0.003									0.001					0.004
90-101.25												0.001					0.001
Σ	5.064	8.768	20.557	4.766	1.887	1.428	1.548	2.295	4.672	8.873	12.771	12.231	7.095	2.527	2.308	3.119	99.908

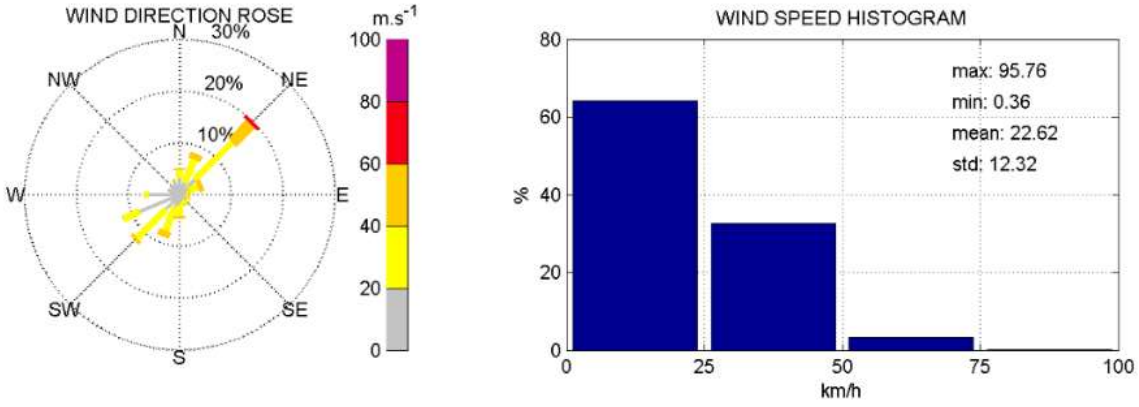


Figure 8: DB103 BLUFF DURBAN PORT CONTROL 2. HEIGHT: 80. Wind climatology from February 2013 to August 2018 based on hourly average. Top: distribution of wind speed and direction. Wind speed categories are defined in the first column and wind direction in the first row. Data is in in percentage. Last row and last column are the total percentage of occurrence per category of direction and speed respectively. Bottom left: Wind rose. Bottom right Wind histogram. Std mean standard deviation. SW wind direction means wind comes from South West. 0.001 % represent roughly two 20 minutes average record.

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-11.25	3.363	3.268	1.622	1.179	0.799	0.693	0.907	0.945	1.044	1.423	4.881	4.260	1.593	1.047	1.465	2.328	30.817
11.25-22.5	8.578	11.422	3.585	2.160	1.036	0.582	1.102	1.310	2.861	3.352	6.767	3.421	0.542	0.071	0.230	0.551	43.570
22.5-33.75	0.485	4.899	1.666	0.573	0.080	0.053	0.049	0.299	3.074	4.647	3.768	0.254	0.020	0.009	0.018	0.009	19.902
33.75-45	0.020	0.308	0.259	0.062	0.004	0.002	0.004	0.015	1.155	2.381	0.684	0.046				0.004	4.946
45-56.25			0.007			0.002	0.002		0.139	0.436	0.080	0.015					0.682
56.25-67.5									0.009	0.038	0.002						0.049
67.5-78.75										0.004			0.002				0.007
78.75-90																	0.000
90-101.25											0.002						0.002
Σ	8.446	19.897	7.138	3.974	1.918	1.332	2.065	2.569	8.282	12.281	16.184	7.997	2.157	1.126	1.713	2.892	99.973

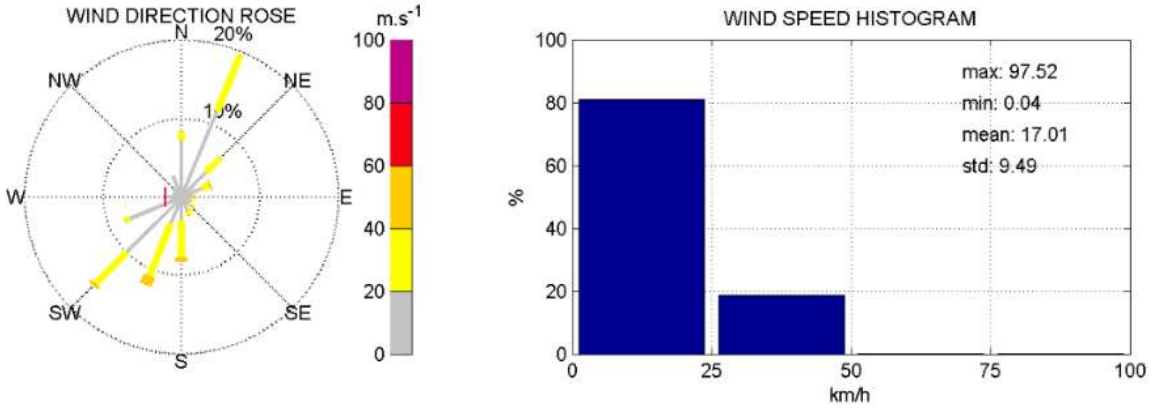


Figure 9: D101 DURBAN WINDNET DURMARINE BUILDING. HEIGHT: 5.0. Wind climatology from February 2013 to August 2018 based on hourly average. Top: distribution of wind speed and direction. Wind speed categories are defined in the first column and wind direction in the first row. Data is in in percentage. Last row and last column are the total percentage of occurrence per category of direction and speed respectively. Bottom left: Wind rose. Bottom right Wind histogram. Std mean standard deviation. SW wind direction means wind comes from South West. 0.002 % represent roughly one one-hour average record.

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-11.25	2.016	2.059	2.141	3.190	2.013	1.252	1.633	1.038	1.529	3.830	7.115	6.447	3.908	3.800	2.247	1.438	45.658
11.25-22.5	0.394	3.090	5.013	4.230	2.046	1.856	1.825	0.532	1.347	3.744	5.595	1.998	1.622	1.983	0.577	0.147	36.000
22.5-33.75	0.004	0.385	4.983	1.927	0.329	2.026	0.363	0.009	0.117	2.154	1.953	0.221	0.947	0.240	0.054	0.004	15.716
33.75-45		0.009	1.107	0.489	0.017	0.389	0.087	0.002		0.160	0.167	0.004	0.052	0.006	0.009	0.002	2.500
45-56.25			0.080	0.017		0.009	0.004				0.006			0.002			0.119
56.25-67.5																	0.000
67.5-78.75												0.002					0.002
78.75-90																	0.000
90-101.25																	0.000
Σ	2.416	5.543	13.324	9.853	4.405	5.532	3.912	1.581	2.993	9.888	14.836	8.672	6.529	6.032	2.887	1.592	99.996

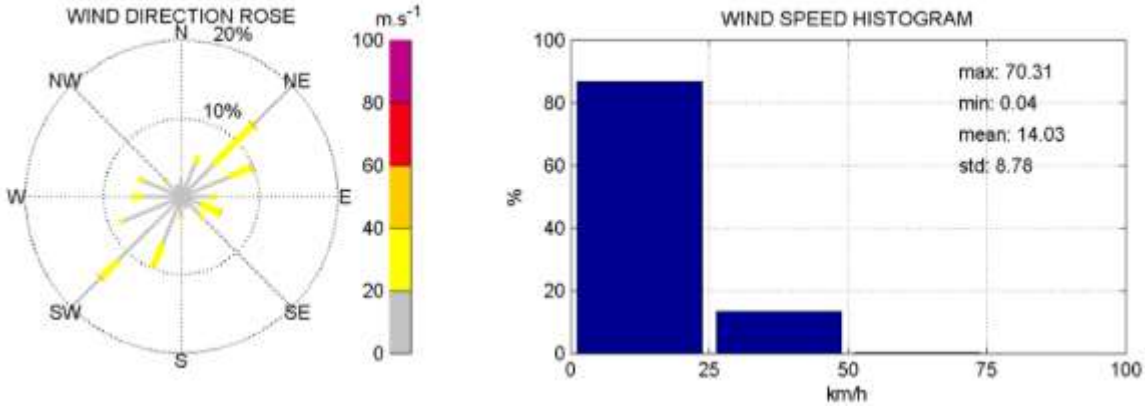


Figure 10: D201 DB WINDNET Container Terminal PIER 2 HEIGHT: 2.5. Wind climatology from February 2013 to August 2018 based on hourly average. Top: distribution of wind speed and direction. Wind speed categories are defined in the first column and wind direction in the first row. Data is in in percentage. Last row and last column are the total percentage of occurrence per category of direction and speed respectively. Bottom left: Wind rose. Bottom right Wind histogram. Std mean standard deviation. SW wind direction means wind comes from South West. 0.002 % represent roughly one one-hour average record.

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-11.25	1.769	0.978	0.930	0.721	0.743	0.691	0.706	0.737	0.769	1.719	3.950	2.442	1.189	1.182	1.312	1.143	20.981
11.25-22.5	3.265	3.629	1.982	1.193	0.741	0.774	1.102	1.819	2.903	6.312	8.441	1.992	0.304	0.584	1.806	2.021	39.867
22.5-33.75	3.454	5.271	2.147	0.426	0.115	0.135	0.248	1.095	4.587	4.209	1.067	0.078	0.004	0.013	0.026	0.315	24.190
33.75-45	1.147	3.889	1.803	0.137	0.030	0.035	0.035	0.278	3.127	0.734	0.169	0.007	0.002	0.002	0.004	0.026	11.427
45-56.25	0.146	1.189	0.584	0.022	0.011	0.011	0.002	0.033	1.110	0.054	0.002	0.002	0.002		0.004	0.013	3.166
56.25-67.5		0.187	0.056			0.002			0.096	0.007							0.348
67.5-78.75									0.011								0.011
78.75-90											0.002						0.002
90-101.25																	0.000
Σ	11.781	15.123	7.503	2.499	1.640	1.647	2.092	3.961	12.602	13.035	13.632	4.522	1.501	1.782	3.153	3.518	99.991

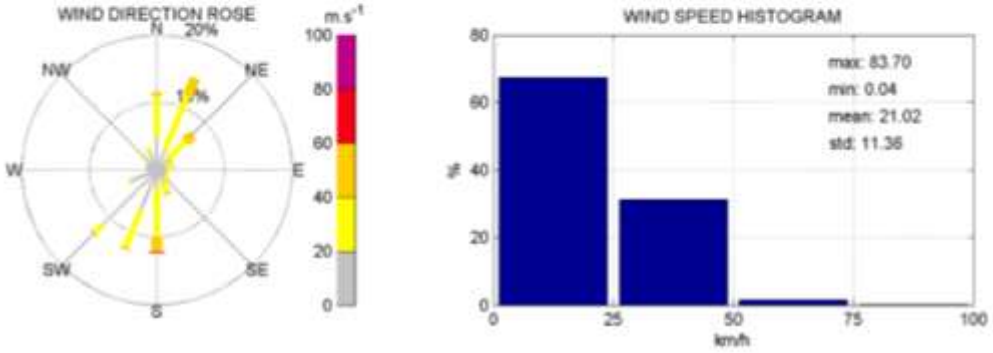


Figure 11: D401 DB WINDNET DURBAN SOUTHERN Breakwater. HEIGHT: 3.0. Wind climatology from February 2013 to August 2018 based on hourly average. Top: distribution of wind speed and direction. Wind speed categories are defined in the first column and wind direction in the first row. Data is in in percentage. Last row and last column are the total percentage of occurrence per category of direction and speed respectively. Bottom left: Wind rose. Bottom right Wind histogram. Std mean standard deviation. SW wind direction means wind comes from South West. 0.002 % represent roughly one one-hour average record.

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-11.25	2.297	2.388	1.929	1.620	1.079	1.172	1.159	1.700	2.692	8.206	17.503	10.397	1.186	0.952	1.489	1.899	57.666
11.25-22.5	3.705	6.656	5.010	2.489	0.742	0.943	0.895	1.150	1.081	0.524	3.536	2.673	0.025	0.027	0.233	0.778	30.469
22.5-33.75	0.480	2.751	4.735	1.248	0.091	0.032	0.002	0.006	0.004		0.013	0.080		0.002	0.008	0.013	9.466
33.75-45		0.273	1.493	0.408	0.025	0.004							0.002		0.002	0.002	2.210
45-56.25		0.004	0.087	0.042								0.002					0.135
56.25-67.5				0.004													0.004
67.5-78.75																	0.000
78.75-90																	0.000
90-101.25																	0.000
Σ	6.482	12.072	13.254	5.812	1.937	2.151	2.056	2.857	3.777	8.730	21.052	13.152	1.214	0.981	1.732	2.692	99.951

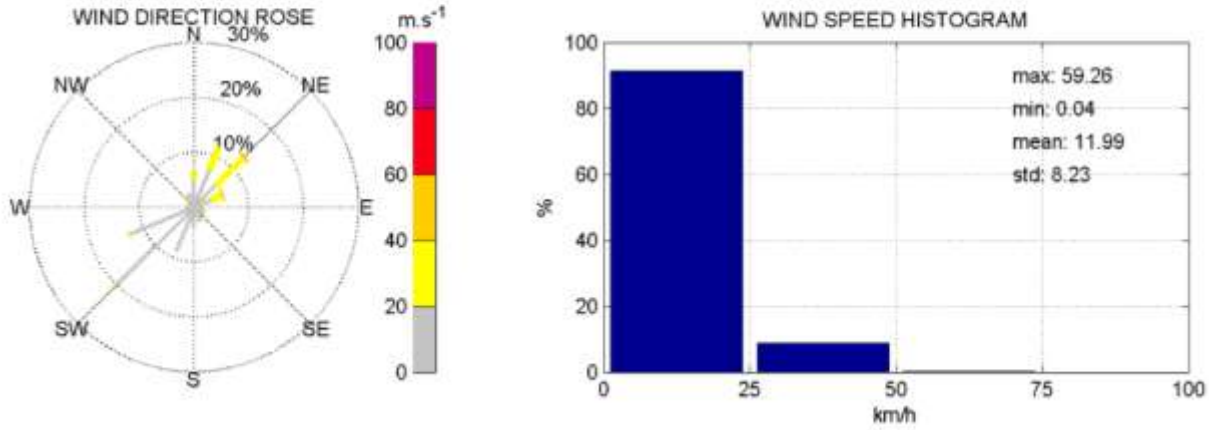


Figure 12: D301 DB WINDNET S.A NAVY BASE HEIGHT: 3.0. Wind climatology from February 2013 to August 2018 based on hourly average. Top: distribution of wind speed and direction. Wind speed categories are defined in the first column and wind direction in the first row. Data is in in percentage. Last row and last column are the total percentage of occurrence per category of direction and speed respectively. Bottom left: Wind rose. Bottom right Wind histogram. Std mean standard deviation. SW wind direction means wind comes from South West. 0.002 % represent roughly one one-hour average record.

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-11.25	2.672	1.083	0.636	0.608	0.556	0.595	0.623	0.571	0.523	0.702	1.473	2.448	2.574	2.755	3.873	5.903	27.597
11.25-22.5	5.974	3.010	2.657	1.253	0.612	0.410	0.549	0.894	1.467	2.600	5.589	4.209	1.138	2.825	3.160	6.474	40.841
22.5-33.75	9.423	4.098	3.682	0.312	0.076	0.059	0.116	0.272	1.469	3.937	2.563	0.248	0.007	0.074	0.052	0.089	17.477
33.75-45	0.031	2.834	2.991	0.078	0.031	0.022	0.013	0.057	0.752	2.701	0.392	0.004	0.002				9.907
45-56.25	0.002	1.112	0.963	0.022	0.009	0.026	0.002	0.017	0.196	1.247	0.046						3.642
56.25-67.5	0.002	0.113	0.057	0.004	0.009		0.002	0.007	0.041	0.253							0.488
67.5-78.75				0.002			0.002	0.004	0.002	0.017							0.028
78.75-90										0.002							0.002
90-101.25									0.002								0.002
Σ	7.104	12.250	10.986	2.280	1.293	1.112	1.308	1.822	4.453	11.459	10.064	6.910	3.721	5.654	7.106	12.466	99.985

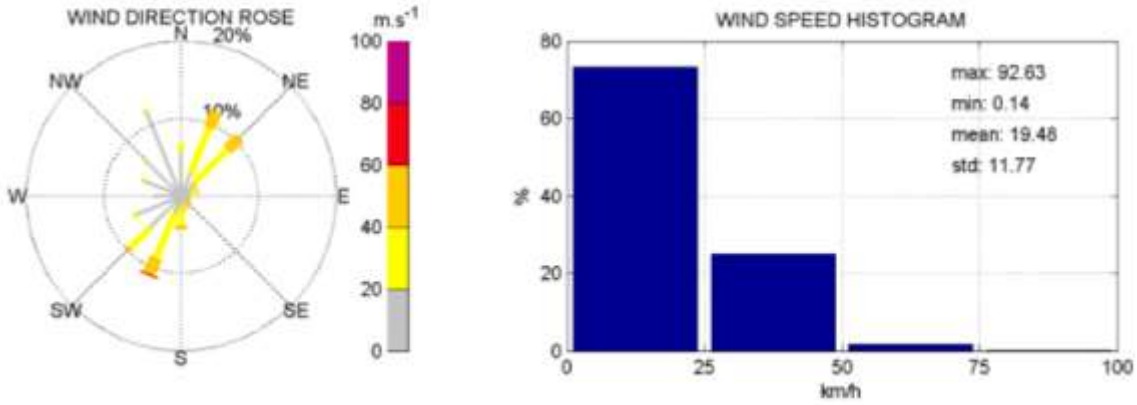


Figure 13: D501 DB WINDNET PORT SHEPSTONE. HEIGHT: 15.0. Wind climatology from February 2013 to August 2018 based on hourly average. Top: distribution of wind speed and direction. Wind speed categories are defined in the first column and wind direction in the first row. Data is in in percentage. Last row and last column are the total percentage of occurrence per category of direction and speed respectively. Bottom left: Wind rose. Bottom right Wind histogram. Std mean standard deviation. SW wind direction means wind comes from South West. 0.002 % represent roughly one one-hour average record.

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-11.25	5.978	0.620	1.367	0.906	0.691	0.622	0.540	0.465	0.579	0.587	0.636	0.919	1.884	2.456	1.207	0.161	19.618
11.25-22.5	4.055	1.315	5.112	3.176	1.609	0.923	0.589	0.641	1.153	1.777	2.074	2.570	4.079	5.643	2.339	0.195	37.250
22.5-33.75	0.612	0.302	4.445	4.346	1.168	0.205	0.080	0.132	0.711	1.847	3.673	3.363	1.014	0.262	0.069		22.229
33.75-45	0.080	0.057	1.347	2.982	0.581	0.019	0.009	0.026	0.271	1.509	3.676	1.374	0.106	0.003			12.039
45-56.25	0.004		0.369	1.739	0.261	0.009	0.007	0.007	0.065	0.906	2.185	0.530	0.022				6.103
56.25-67.5	0.001		0.067	0.555	0.071				0.007	0.385	0.928	0.170					2.183
67.5-78.75			0.001	0.031	0.002			0.001	0.001	0.072	0.292	0.029					0.428
78.75-90										0.011	0.083	0.003					0.098
90-101.25										0.012	0.021						0.033
Σ	10.731	2.294	12.708	13.733	4.382	1.779	1.226	1.272	2.786	7.103	13.567	8.957	7.105	8.364	3.616	0.356	99.980

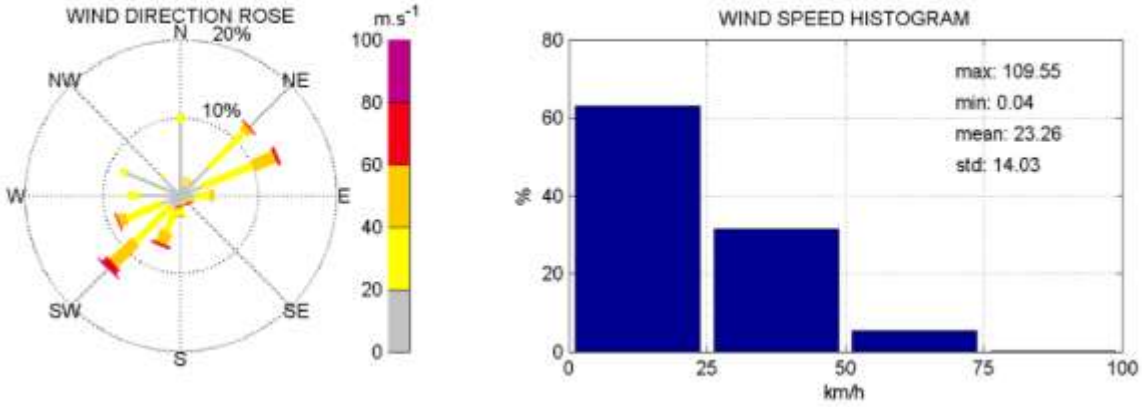


Figure 14: D601 DB TUGELA RIVER LIGHTHOUSE. Height 22 m. Wind climatology from February 2013 to August 2018 based on 20-minutes average. Top: distribution of wind speed and direction. Wind speed categories are defined in the first column and wind direction in the first row. Data is in in percentage. Last row and last column are the total percentage of occurrence per category of direction and speed respectively. Bottom left: Wind rose. Bottom right Wind histogram. Std mean standard deviation. SW wind direction means wind comes from South West. 0.001 % represent roughly one 20-minute average record.

Wind gust climatology

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-20	2.449	1.741	2.785	1.382	1.075	0.934	0.970	1.118	1.427	1.419	1.655	4.881	4.919	2.242	2.093	2.743	33.831
20-40	2.381	5.198	8.878	2.134	0.700	0.461	0.534	1.051	2.358	4.320	6.091	6.425	2.100	0.276	0.201	0.363	43.470
40-60	0.223	1.641	6.986	0.983	0.098	0.029	0.038	0.123	0.838	2.480	4.054	0.845	0.067	0.007	0.010	0.008	18.431
60-80	0.012	0.186	1.780	0.253	0.010	0.003	0.004	0.002	0.048	0.602	0.898	0.075	0.008		0.004	0.005	3.891
80-100	0.001	0.002	0.126	0.015	0.004	0.001	0.001		0.001	0.048	0.068	0.004					0.272
100-120			0.001	0.001						0.003	0.005		0.001	0.001			0.012
120-140																	0.000
140-160												0.001		0.001			0.002
160-180																	0.000
Σ	5.064	8.768	20.557	4.767	1.887	1.428	1.548	2.295	4.672	8.873	12.771	12.231	7.095	2.527	2.308	3.119	99.908

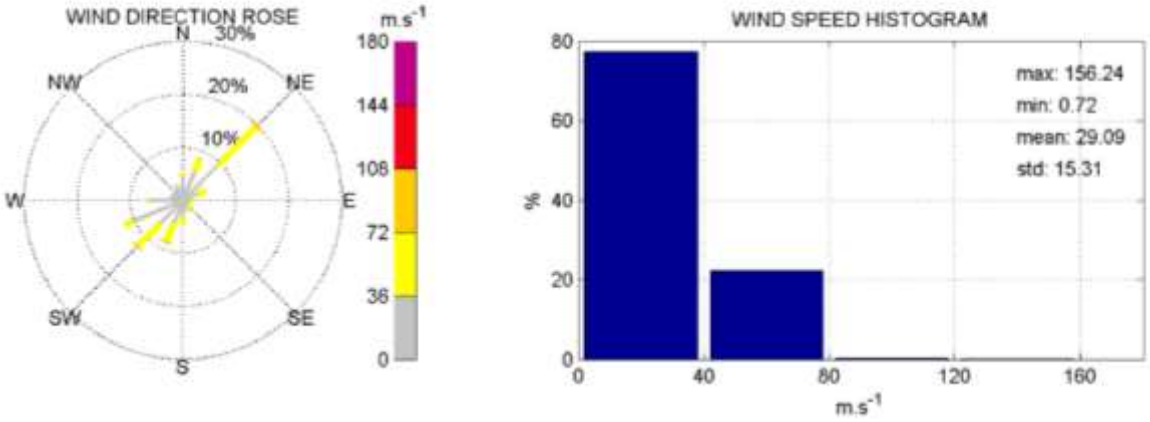


Figure 15 : DB103 DURBAN PORT CONTROL 2. HEIGHT: 80. Wind gust climatology from February 2013 to August 2018 during 20-minute period. Top: distribution of wind speed and direction. Wind speed categories are defined in the first column and wind direction in the first row. Data is in in percentage. Last row and last column are the total percentage of occurrence per category of direction and speed respectively. Bottom left: Wind rose. Bottom right Wind histogram. Std mean standard deviation. SW wind direction means wind comes from South West. 0.001 % represent roughly two records.

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-20	3.144	3.018	1.620	1.252	0.724	0.549	0.823	0.859	0.881	1.255	5.441	5.021	1.644	1.009	1.334	2.292	30.865
20-40	4.691	11.524	3.651	2.277	1.122	0.728	1.193	1.494	3.321	3.381	7.138	2.770	0.496	0.104	0.350	0.575	44.814
40-60	0.575	4.932	1.651	0.423	0.064	0.049	0.042	0.201	2.947	4.799	3.038	0.159	0.013	0.007	0.024	0.011	18.937
60-80	0.031	0.416	0.217	0.022	0.009	0.004	0.004	0.011	0.989	2.343	0.516	0.042	0.002	0.007	0.004	0.013	4.631
80-100	0.004	0.007				0.002	0.002	0.004	0.137	0.462	0.046	0.004					0.670
100-120									0.009	0.038	0.002						0.049
120-140										0.002			0.002				0.004
140-160																	0.000
160-180											0.002						0.002
Σ	8.446	19.897	7.138	3.974	1.918	1.332	2.064	2.569	8.284	12.281	16.184	7.997	2.157	1.126	1.713	2.892	99.973

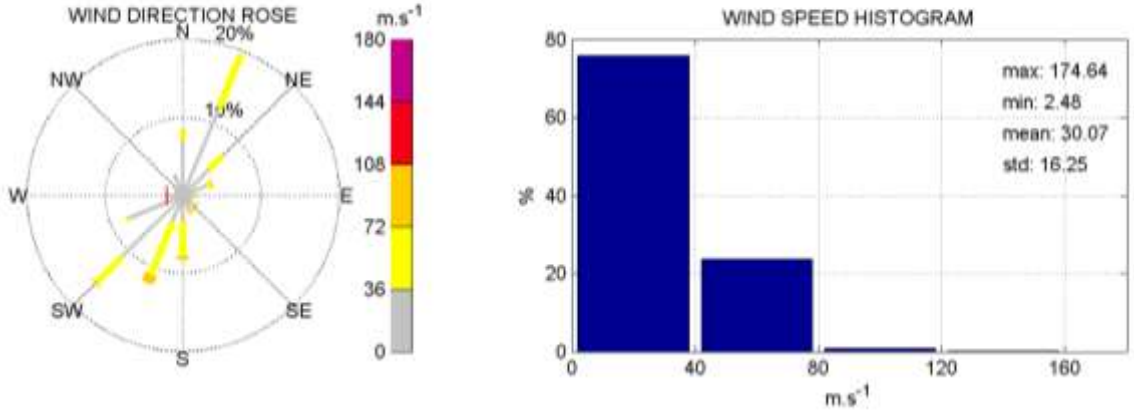


Figure 16: D101 DURBAN WINDNET DURMAR BUILDING. HEIGHT: 5.0. Wind gust climatology from February 2013 to August 2018 during an hourly period. Top: distribution of wind speed and direction. Wind speed categories are defined in the first column and wind direction in the first row. Data is in in percentage. Last row and last column are the total percentage of occurrence per category of direction and speed respectively. Bottom left: Wind rose. Bottom right Wind histogram. Std mean standard deviation. SW wind direction means wind comes from South West. 0.002 % represent roughly one record.

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-20	2.009	2.074	2.325	4.053	1.957	1.163	1.881	0.889	1.179	3.315	5.802	5.733	3.653	3.302	2.217	1.395	42.946
20-40	0.389	3.162	6.669	4.444	2.165	2.775	1.806	0.666	1.615	3.555	6.261	2.584	1.533	2.150	0.599	0.184	40.556
40-60	0.015	0.298	4.063	1.265	0.279	1.529	0.208	0.024	0.190	2.595	2.470	0.342	1.157	0.554	0.061	0.009	15.058
60-80	0.002	0.009	0.264	0.089	0.004	0.065	0.013	0.002	0.009	0.407	0.296	0.011	0.175	0.024	0.011	0.004	1.384
80-100			0.002	0.002			0.004			0.015	0.006		0.013				0.043
100-120											0.004			0.002			0.006
120-140																	0.000
140-160												0.002					0.002
160-180																	0.000
Σ	2.416	5.543	13.323	9.853	4.405	5.532	3.912	1.581	2.993	9.887	14.839	8.672	6.531	6.031	2.887	1.592	99.996

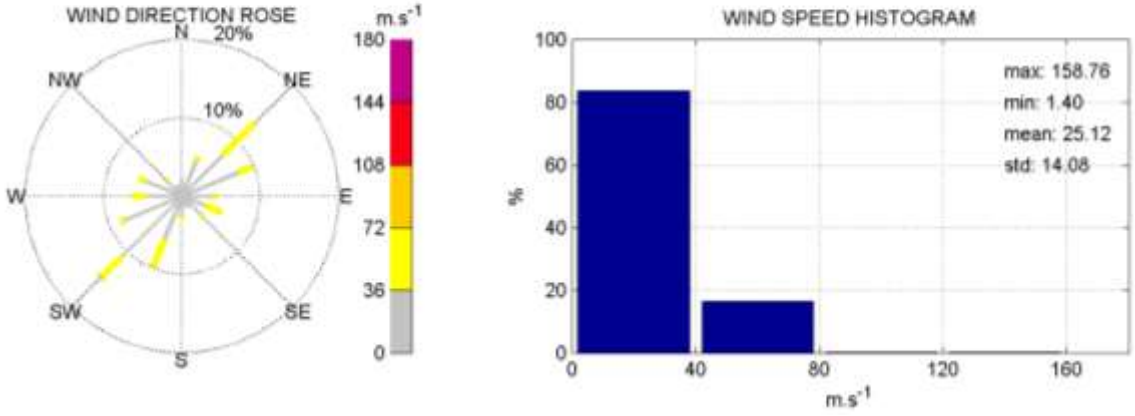


Figure 17: D201 DB WINDNET CONT TERMI PIER 2 HEIGHT: 2.5. Wind gust climatology from February 2013 to August 2018 based on hourly maximum. Top: distribution of wind speed and direction. Wind speed categories are defined in the first column and wind direction in the first row. Data is in in percentage. Last row and last column are the total percentage of occurrence per category of direction and speed respectively. Bottom left: Wind rose. Bottom right Wind histogram. Std mean standard deviation. SW wind direction means wind comes from South West. 0.002 % represent roughly one record.

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-20	2.272	1.526	1.361	0.960	0.960	0.962	0.941	1.110	0.939	1.669	6.574	3.401	1.290	1.426	2.007	1.669	29.086
20-40	6.962	6.962	3.180	1.329	0.579	0.600	1.030	2.248	4.203	6.164	6.063	1.060	0.204	0.340	1.131	1.734	43.788
40-60	2.360	5.536	2.482	0.191	0.076	0.082	0.119	0.555	5.042	4.214	0.887	0.061	0.013	0.020	0.015	0.106	21.757
60-80	0.176	1.040	0.455	0.020	0.009	0.007	0.004	0.050	2.120	0.860	0.080	0.007	0.002		0.011	0.020	4.860
80-100	0.004	0.035	0.020			0.002		0.002	0.286	0.111	0.007	0.002					0.468
100-120		0.002							0.017	0.007			0.002				0.028
120-140										0.002							0.002
140-160											0.002						0.002
160-180																	0.000
Σ	11.774	15.101	7.497	2.499	1.643	1.654	2.094	3.964	12.606	13.027	13.612	4.530	1.511	1.786	3.165	3.529	99.991

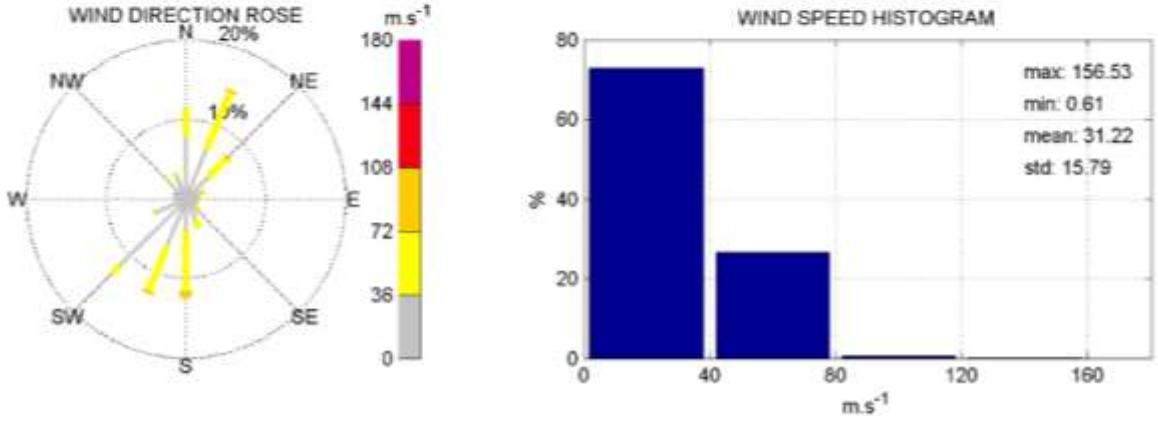


Figure 18: D401 DB WINDNET DUR SOUTHERN BW. HEIGHT: 3.0. Wind gust climatology from February 2013 to August 2018 based on hourly maximum. Top: distribution of wind speed and direction. Wind speed categories are defined in the first column and wind direction in the first row. Data is in in percentage. Last row and last column are the total percentage of occurrence per category of direction and speed respectively. Bottom left: Wind rose. Bottom right Wind histogram. Std mean standard deviation. SW wind direction means wind comes from South West. 0.002 % represent roughly one record.

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-20	2.178	2.535	2.444	1.986	1.043	1.106	0.865	0.981	0.905	3.935	9.903	8.822	1.129	0.926	1.548	1.884	42.191
20-40	3.937	7.536	6.881	3.045	0.804	1.009	1.161	1.791	2.271	3.654	9.535	4.075	0.080	0.051	0.167	0.780	46.777
40-60	0.355	1.903	3.673	0.730	0.085	0.032	0.027	0.087	0.594	1.106	1.567	0.254	0.002	0.004	0.011	0.023	10.453
60-80	0.011	0.087	0.254	0.044	0.006	0.002	0.002	0.002	0.011	0.032	0.040	0.002			0.006	0.004	0.503
80-100		0.008		0.006		0.002					0.004		0.002				0.023
100-120										0.002							0.002
120-140												0.002					0.002
140-160																	0.000
160-180																	0.000
Σ	6.481	12.070	13.252	5.811	1.937	2.151	2.055	2.861	3.781	8.729	21.049	13.155	1.214	0.981	1.732	2.692	99.951

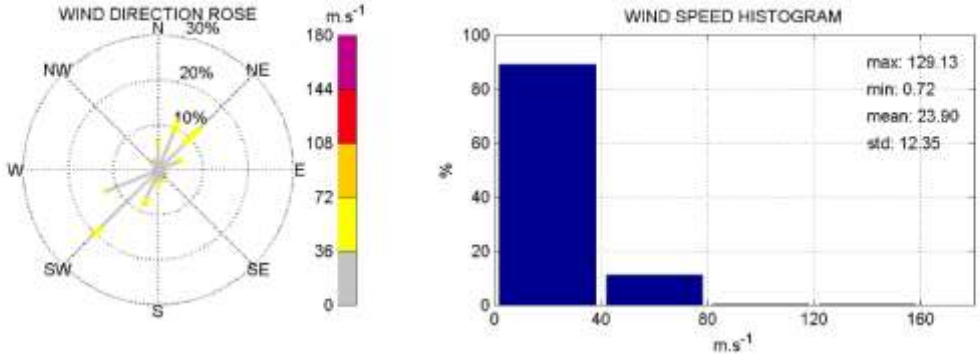


Figure 19: D301 DB WINDNET S.A NAVY BASE HEIGHT: 3.0. Wind gust climatology from February 2013 to August 2018 during an hourly period. Top: distribution of wind speed and direction in %. Wind speed categories are defined in the first column and wind direction in the first row. Data is in in percentage. Last row and last column are the total percentage of occurrence per category of direction and speed respectively. Bottom left: Wind rose. Bottom right Wind histogram. Std mean standard deviation. SW wind direction means wind comes from South West. 0.002 % represent roughly one record.

.

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-20	2.562	1.155	1.028	0.859	0.769	0.700	0.793	0.756	0.767	0.801	1.174	2.020	2.335	3.397	4.845	8.667	32.628
20-40	4.016	4.593	5.209	1.279	0.471	0.362	0.493	0.925	2.268	4.078	5.385	4.342	1.305	2.129	2.076	3.582	42.513
40-60	0.458	5.321	4.115	0.150	0.058	0.071	0.058	0.141	1.202	4.580	2.887	0.441	0.036	0.092	0.144	0.118	19.872
60-80	0.043	1.052	0.527	0.013	0.013	0.026	0.004	0.026	0.218	1.763	0.536	0.062	0.009	0.004	0.030	0.032	4.357
80-100	0.009	0.021	0.013	0.006	0.006			0.011	0.024	0.246	0.071	0.013	0.002		0.002	0.011	0.435
100-120	0.002		0.002	0.002	0.002		0.004			0.006	0.004	0.002	0.002	0.004	0.002	0.011	0.045
120-140	0.002						0.002		0.002	0.009	0.002	0.002	0.002	0.004		0.006	0.032
140-160		0.002			0.002				0.004	0.002			0.004	0.002		0.004	0.021
160-180		0.002	0.002				0.002			0.002				0.002		0.004	0.015
Σ	7.092	12.145	10.897	2.309	1.322	1.159	1.356	1.859	4.485	11.488	10.059	6.882	3.695	5.636	7.099	12.435	99.919

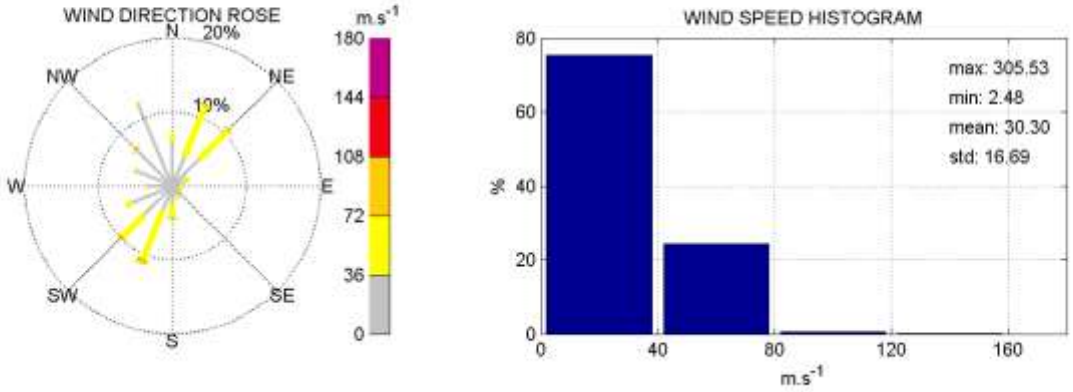


Figure 20: D501 DB WINDNET PORT SHEPSTONE. HEIGHT: 15.0. Wind gust climatology from February 2013 to August 2018 during an hourly period. Top: distribution of wind speed and direction. Wind speed categories are defined in the first column and wind direction in the first row. Data is in in percentage. Last row and last column are the total percentage of occurrence per category of direction and speed respectively. Bottom left: Wind rose. Bottom right Wind histogram. Std mean standard deviation. SW wind direction means wind comes from South West. 0.002 % represent roughly one record. NB need to be replaced du to spurious values in maximum gust (305 km/h).

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-20	6.938	1.025	2.216	1.659	1.174	0.971	0.777	0.707	0.933	1.046	0.949	1.164	3.184	5.849	2.744	0.311	31.647
20-40	3.283	1.085	7.092	6.066	2.186	0.764	0.421	0.511	1.392	2.727	4.000	4.046	3.517	2.488	0.870	0.045	40.494
40-60	0.470	0.172	2.954	4.543	0.826	0.033	0.020	0.045	0.390	2.101	5.114	2.803	0.357	0.024	0.002		19.853
60-80	0.030	0.013	0.442	1.412	0.189	0.012	0.007	0.008	0.067	0.967	2.589	0.766	0.045	0.003			6.549
80-100	0.006		0.004	0.052	0.007		0.001		0.003	0.229	0.748	0.167	0.003				1.220
100-120	0.003							0.001		0.026	0.144	0.010					0.184
120-140	0.001			0.001					0.001	0.008	0.027						0.037
140-160											0.005	0.001					0.006
160-180																	0.000
Σ	10.731	2.294	12.708	13.733	4.382	1.779	1.226	1.272	2.786	7.105	13.576	8.957	7.105	8.364	3.616	0.356	99.990

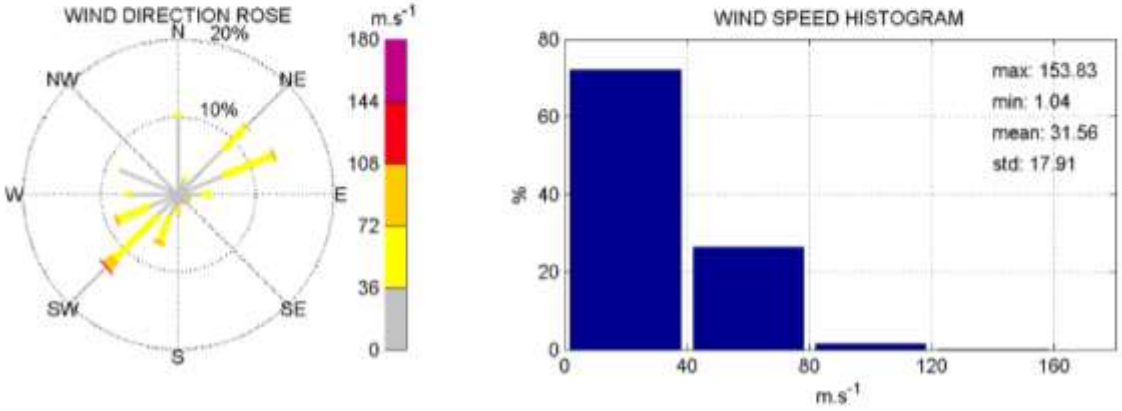


Figure 21: D601 DB TUGELA RIVER LIGHT HOUSE. Height 22 m. Wind gust climatology from February 2013 to August 2018 for 20 minutes periods. Top: distribution of wind speed and direction. Wind speed categories are defined in the first column and wind direction in the first row. Data is in in percentage. Last row and last column are the total percentage of occurrence per category of direction and speed respectively. Bottom left: Wind rose. Bottom right Wind histogram. Std mean standard deviation. SW wind direction means wind comes from South West. 0.001 % represent roughly two records.

THE WEATHER CONDITIONS WHICH PREVAILED

Introduction

62. The weather system that affected Durban on the 10 of October 2017 was the result of the interaction of an upper air cut-off low system and a low-pressure system centred offshore of Durban. A High-pressure system ridging to the west of Durban further added moisture to the region.
63. The cut off low affected most of South Africa from the 9 to the 11 of October slowly moving from west to east. This led to severe thunderstorm, tornadoes, strong wind and flood inland in numerous locations of South Africa.
64. Figure 22 shows the vertical structure of a cut-off low. Cut-off lows are responsible also for many serious flooding in South Africa.
65. The cut-off low is a well-known low-pressure system that occurs several times a year in South Africa.

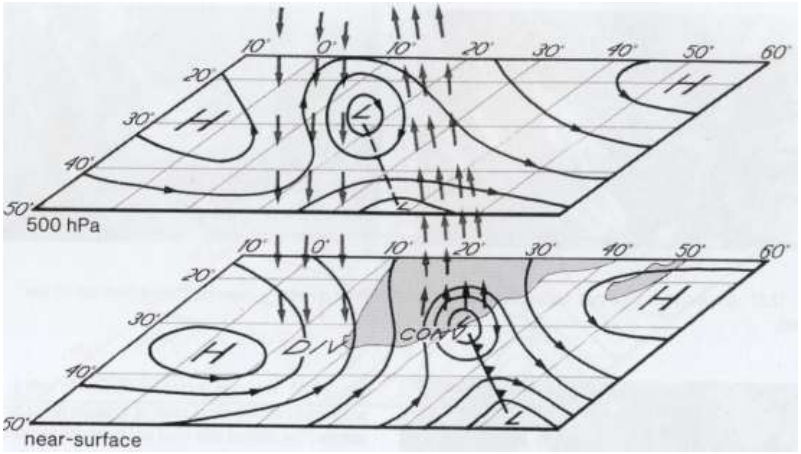


Figure 22: Surface expression and mid-tropospheric expression of a cut-off low. The bottom panel is the near surface while the top panel indicates high (H) and low(L) pressure in the middle of the troposphere, at a height of roughly 5000m. The L roughly

represent the centre of a cut-off low (Copied from the book Weather and Climate of South Africa by Tyson and Preston-White).

66. The low-pressure system was generated on the 10 offshore and was also produced by the cut-off low. The low-pressure system and the ridging high pressure system the west brought moist air from the ocean further feeding land in energy and moisture at the surface while the cut off low provided cold air at heights favouring intense convection and the development of severe thunderstorm in Kwazulu-Natal.
67. The analysis is confirmed by a report done by Kevin Rae chief forecaster at the SAWS Pretoria.
68. The low-pressure system is seen in the SAWS synoptic weather chart off Durban on the 10 10 2017 charts and marked with a “L while the ridging high pressure to the west is marked with a H. flow is anticyclonic(anti-clockwise) for high pressure system and cyclonic (clockwise) for low pressure system and follow the isobaric line drawn on the Sea Level Pressure charts
69. Typical low-pressure system affecting south Africa and leading to strong wind and floods are cut off low, cold front, coastal low and mesoscale convective system.
70. Severe thunderstorms or tornadoes do not occur in all locations that are under the influence of cut off low, mesoscale convective system, coastal low or low-pressure systems.
71. The cut off low is seen in blue on the 500 hPa geopotential height chart GFS hindcast and forecast on the 9 10 and 11 of October 2017.

Interpretation of charts from the Global Forecast System (GFS)

72. 500mb Geopotential Height and Vorticity: Black contours indicate the geopotential height of the 500 millibar surface, in tens of meters. Low geopotential height (compared to other locations at the same latitude) indicates the presence of a storm or trough at mid-troposphere levels. Relatively high geopotential height indicates a ridge, and quiescent weather. The color shaded contours indicate vorticity at 500 millibars: Red for positive vorticity, blue for negative. Positive vorticity indicates counter clockwise rotation of the winds, and/or lateral shear of the wind with stronger flow to the right of the direction of flow. Negative vorticity indicates clockwise rotation of the winds, and/or lateral shear of the wind with stronger flow to the left of the direction of flow. Negative vorticity at 500 millibars in blue is associated with cyclones, low pressure system or storms at upper levels of the atmosphere and will tend to coincide with troughs in the geopotential height field. Positive vorticity in red is associated with calm weather and will tend to coincide with ridges in the geopotential height field.
73. Sea Level Pressure and 1000-500mb Thickness: it is like the SAWS Sea level pressure chart. The coloured contour lines indicate sea level pressure in millibars. High pressure is red, low pressure in green or blue. Only the last 2 digits shown -- sea level pressure is usually around 1000 millibars, so add 1000 to values in the range of 00-50 and add 900 to values in the range of 50-98. Low sea level pressure indicates cyclones, low pressure systems or storms near the surface of the earth. High sea level pressure indicates calm weather and high-pressure systems. The shaded contours indicate the vertical distance, or thickness, between the 1000 millibar surface and the 500 millibar

surface, measured in tens of meters. Since air behaves nearly as an ideal gas, and vertical distance is proportional to volume over a specified surface area, the thickness between two pressure levels is proportional to the mean temperature of the air between those levels. Thus, low values of thickness mean relatively cold air.

74. Vertical Velocity or Precipitation: The vertical velocity at 700mb (in mb/hr) is shown instead of accumulated precipitation for the analysis. Negative values indicate ascending air, and positive values denote sinking air. Ascending motion is associated with cloudiness and rain. Large negative values of vertical velocity correspond to areas of heavy rainfall if moisture is available. The remaining forecast panels indicate 12 or 24 hour accumulated precipitation, measured in millimetres. The total is the amount of rainfall forecast during the 12 or 24 hours immediately preceding the verification time in the lower left-hand corner of the map. The with the 540-thickness line and the 0 °C isotherm at 850mb can give a good indication of the dividing line between snow and rain.

Description of the weather pattern that prevailed from 9 10 2017 to 11 10 2017

75. Figure 23 below show the historical sea level pressure on the 8 10 2017. An historical SAWS charts is a chart made in retrospection after the date of forecasting. Low pressure systems are marked with a L while high pressures systems are marked with an H. On that day a cold front marked by the thick barbed lines situated south of the country while a High pressure is ridging to the West. A discussion of the weather is shown on the left of the chart.

76. Figure 24 below show the historical sea level pressure on the 9 10 2017. A High pressure is ridging to South of the country bring moist air inland.

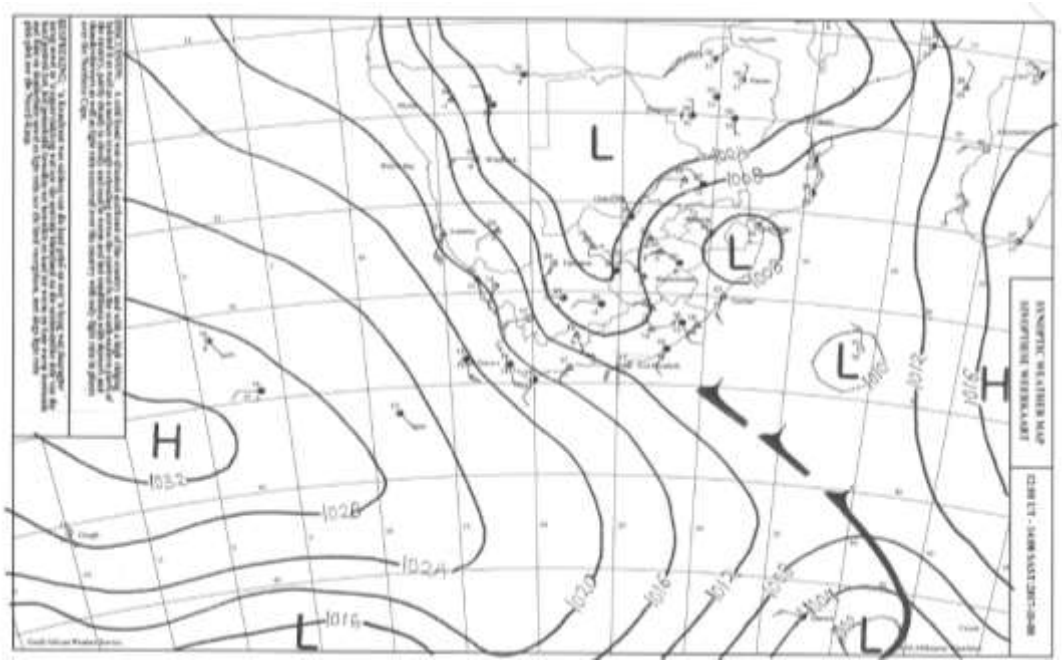


Figure 23: SAWS historical synoptic chart and summary 1400 SAST 8 10 2017

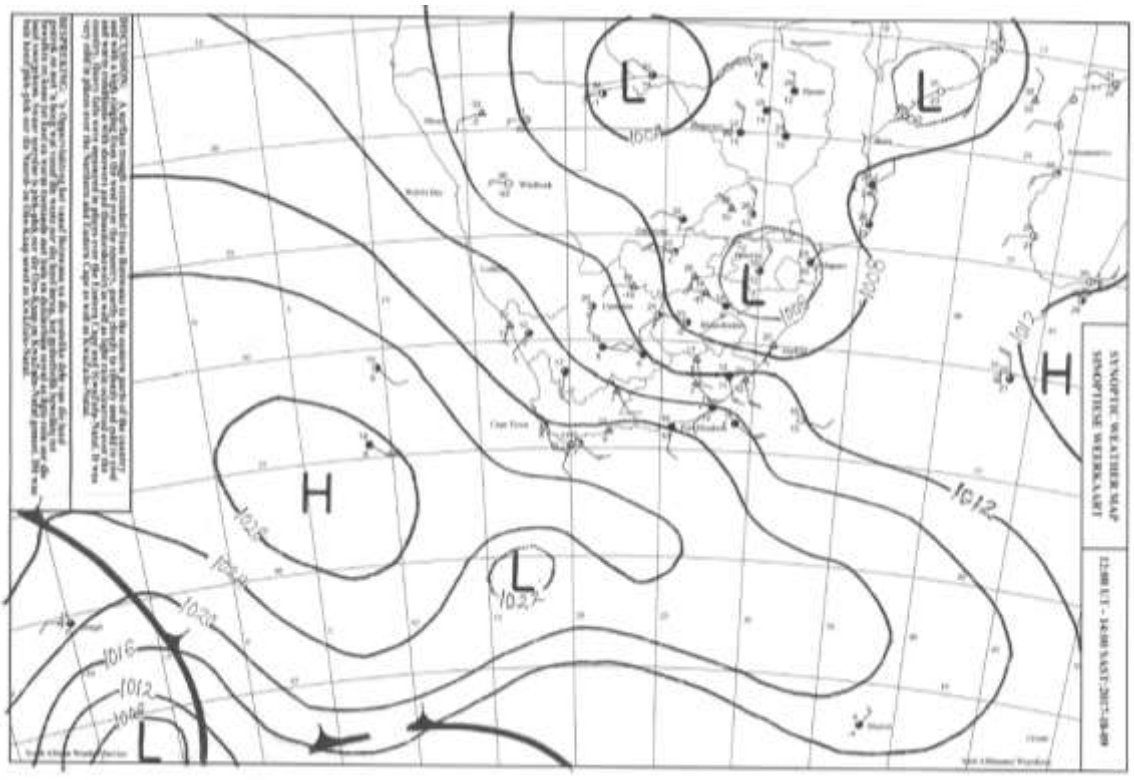
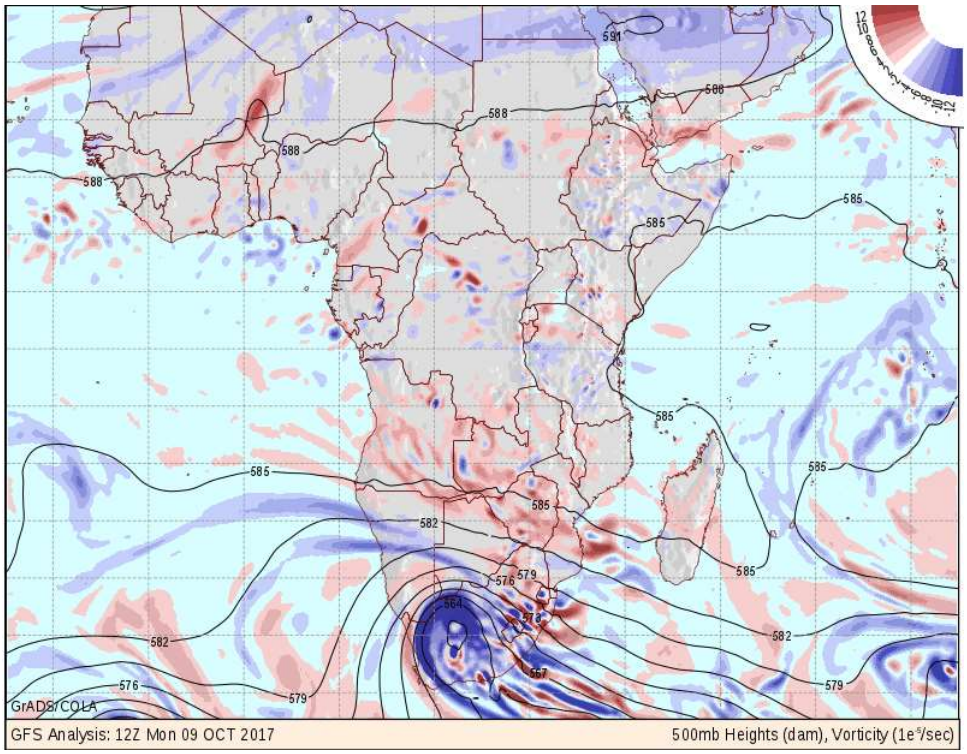


Figure 24: SAWS historical synoptic chart and summary 1400 SAST 9 10 2017

77. Figure 25 below show the 500mb Geopotential Height and Vorticity analysis or hindcast on the 9 10 2017. Th cut-off low is seen in blue above South Africa.

The analysis would be like condition prevailing at the time of a forecast done on the 9 of October 2017.



F

Figure 25: 09 10 2017 12 PM GFS analysis (hindcast) of 500 hPa geopotential heights and vorticity. Blue show the extend of the cut-off low.

78. Figure 26 below show the GFS Sea Level Pressure and 1000-500mb Thickness analysis (hindcast) on the 9 10 2017. It is like the SAWS SLP charts. The analysis would be like condition prevailing at the time of a forecast done on the 9 of October 2017.

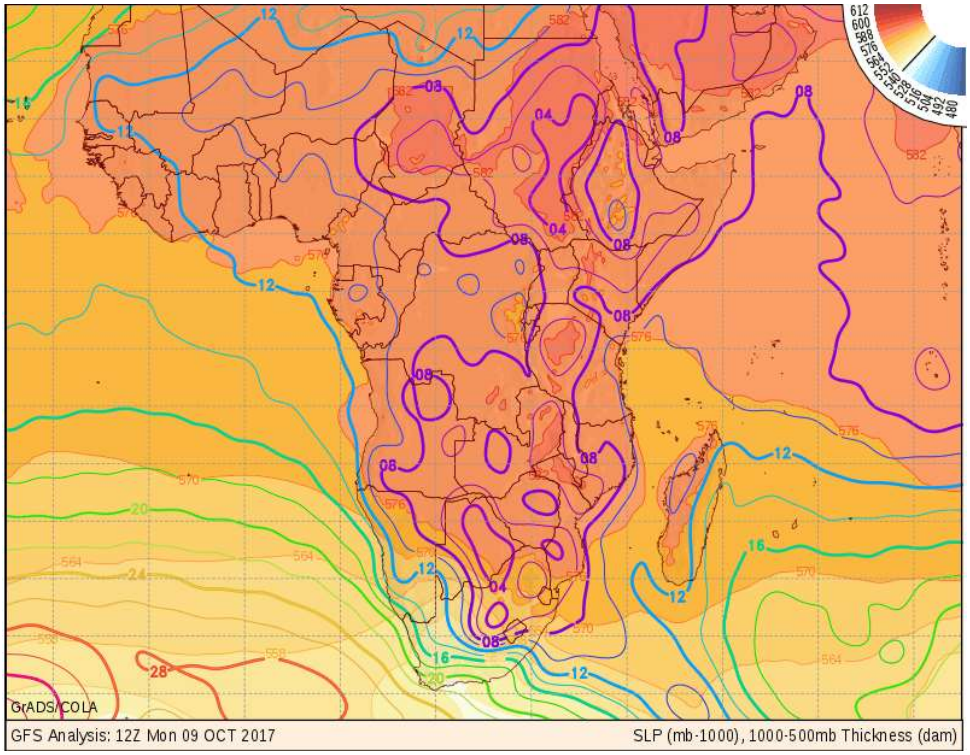


Figure 26: 09 10 2017 12 PM GFS analysis of surface level pressure. Purple line shows are of low pressure.

79. Figure 27 below show the SAWS sea level pressure charts on the 10 10 2017 available on the 10 10 2017 to all forecaster. A High pressure is ridging South of the country bring moist air inland. A low pressure is observed of Durban in the Ocean bringing moisture inland. The cut off low being often a high atmospheric level feature is better seen in Figure 29.
80. Figure 28 below show the historical SAWS sea level pressure charts on the 10 10 2017. It is like Figure 27 A High pressure is ridging South of the country bring moist air inland. A low pressure is observed of Durban in the Ocean bringing moisture inland. The cut off low being often a high atmospheric level feature is better seen in Figure 29. The cut off low is mentioned in the caption to the left of Figure 28.

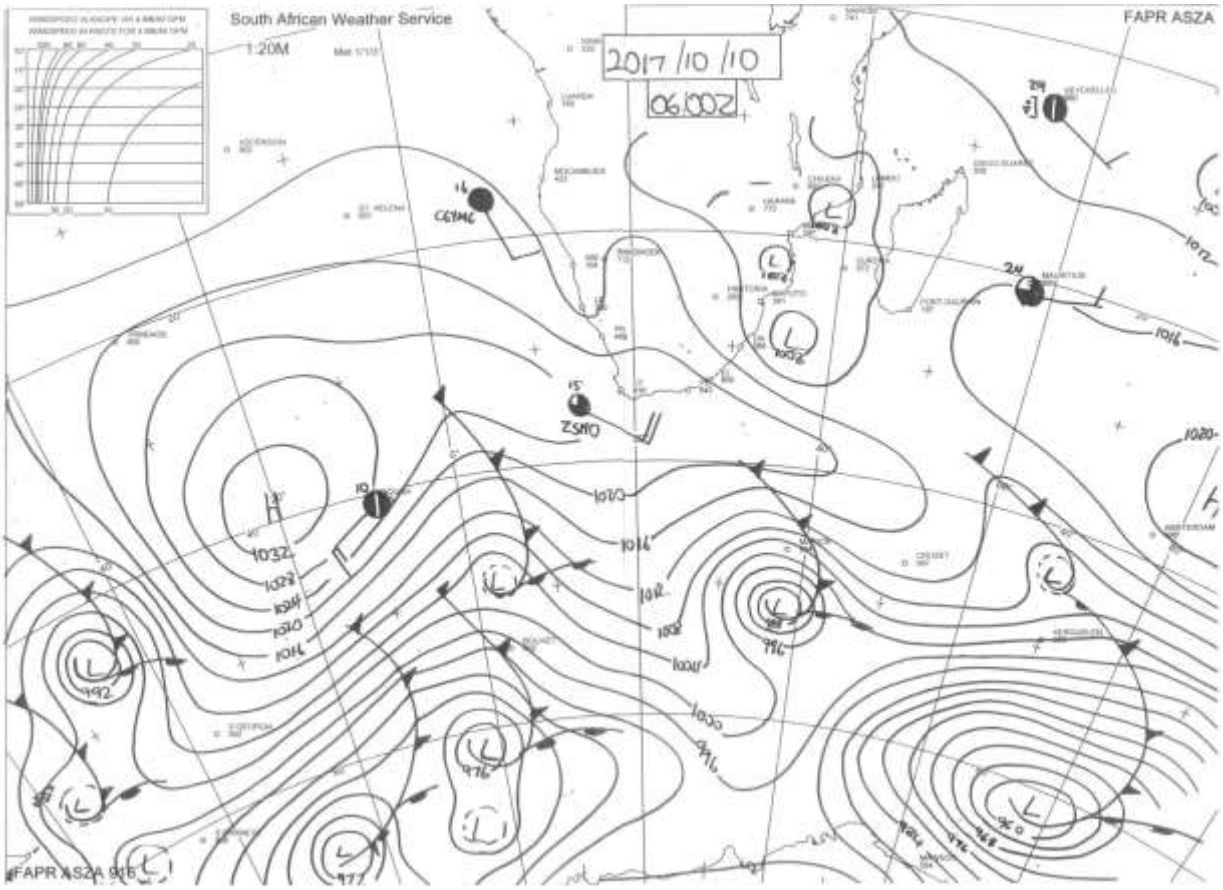


Figure 27: SAWS synoptic chart at 06:00 10 10 2017 available on SAWS web site on the 10 10 2017

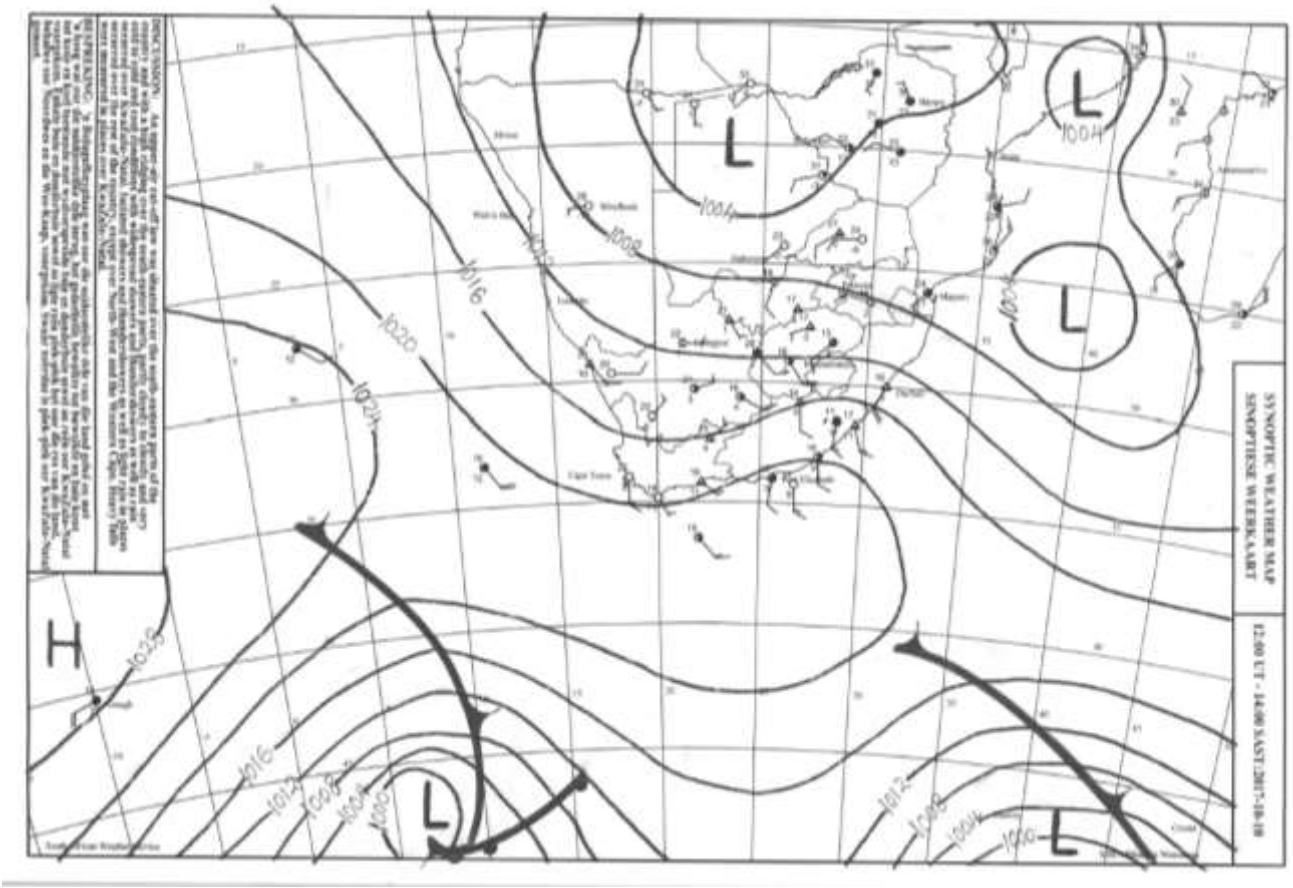


Figure 28: SAWS historical synoptic chart and summary 1400 SAST 10 10 2017

81. Figure 29 below show the 10 10 2017 forecasted 500mb Geopotential Height and Vorticity analysis done on the 9 10 2017. The cut-off low is seen in blue above South Africa.

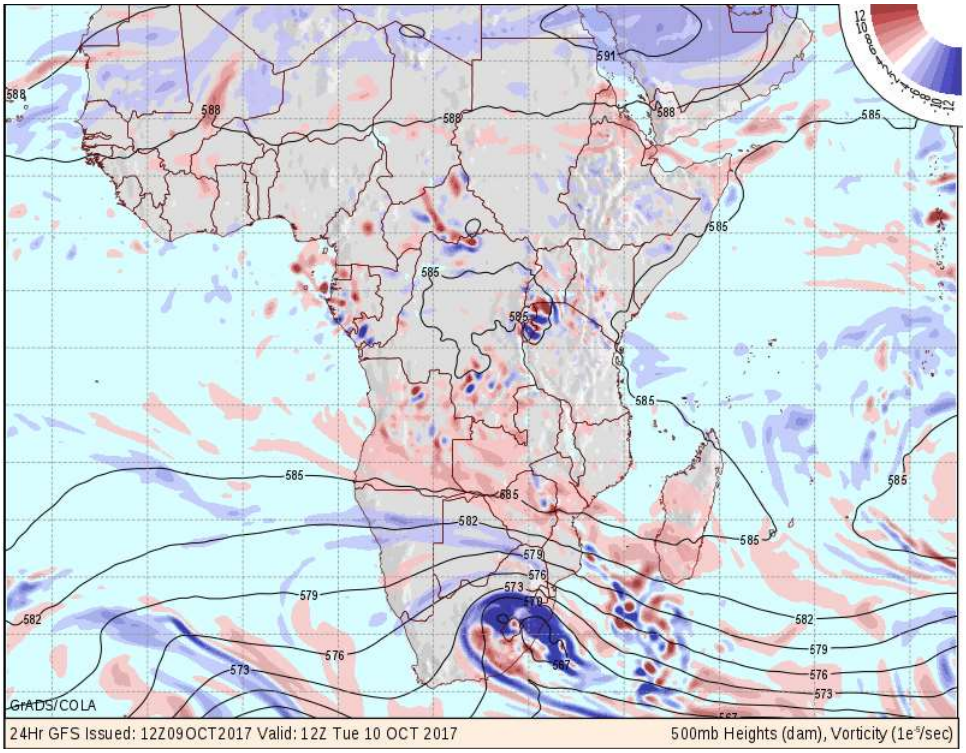


Figure 29: 10 10 2017 12 PM forecast done on 9 10 2017 of 500 hPa geopotential heights and vorticity. Blue show the extend of the cut-off low.

82. Figure 30 below show the 10 10 2017 forecasted GFS Sea Level Pressure and 1000-500mb. It is like the SAWS SLP charts except that the low pressure off Durban is less marked but still present.

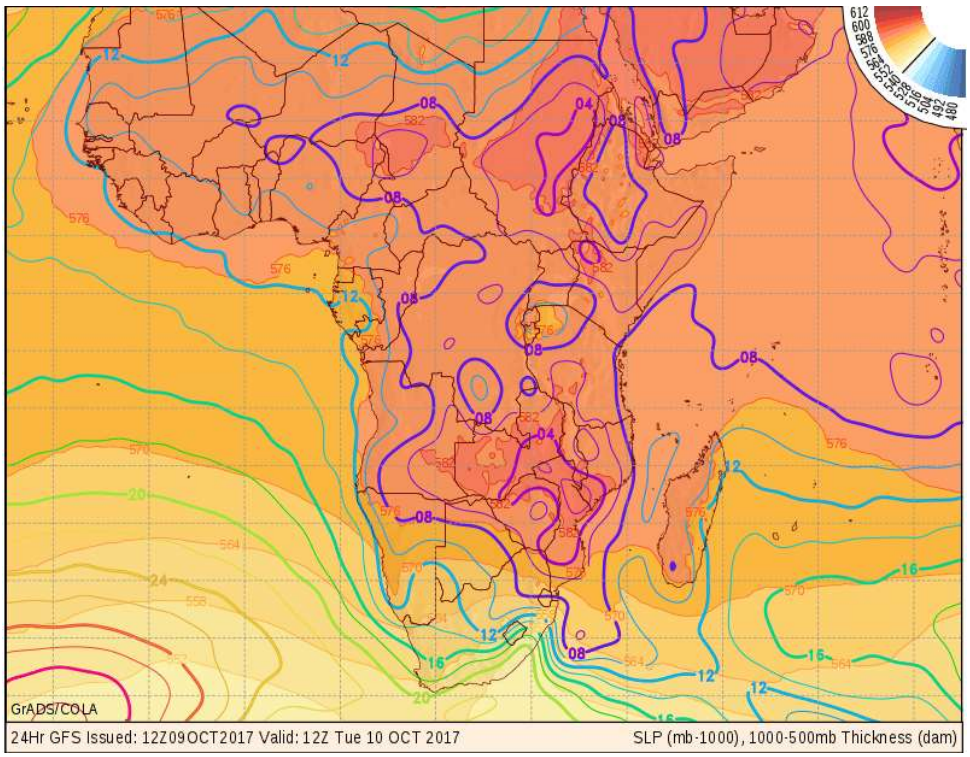


Figure 30: 10 10 2017 12 PM forecast done on 9 10 2017 of surface level pressure. Purple line shows are of low pressure

83. Figure 31 below show the 10 10 2017 forecasted precipitation. It shows the wide extent of precipitation forecasted that day. Yellow is about 35 mm of rain. Red about 60 mm and dark red 80 mm.

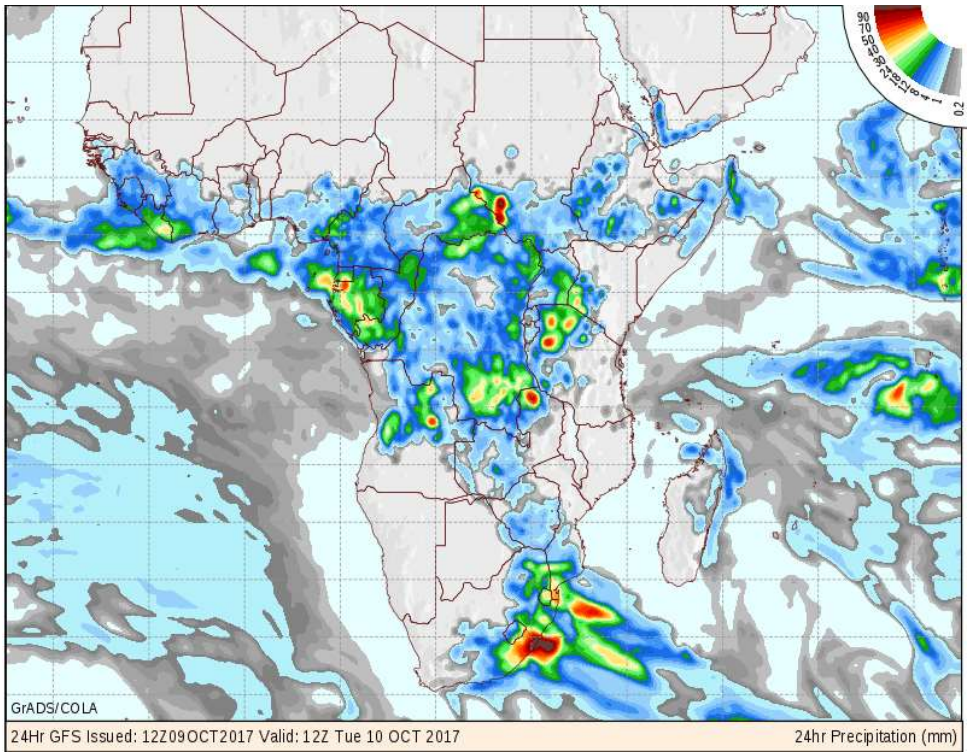


Figure 31: forecasted cumulative precipitation from 9 10 2017 12 PM to 10 10 2017 12. Forecast done on the 9 10 2017.

84. Figure 32 to 35 are showing forecast and analysis charts for the 11 10 2017 showing the weather clearing up.

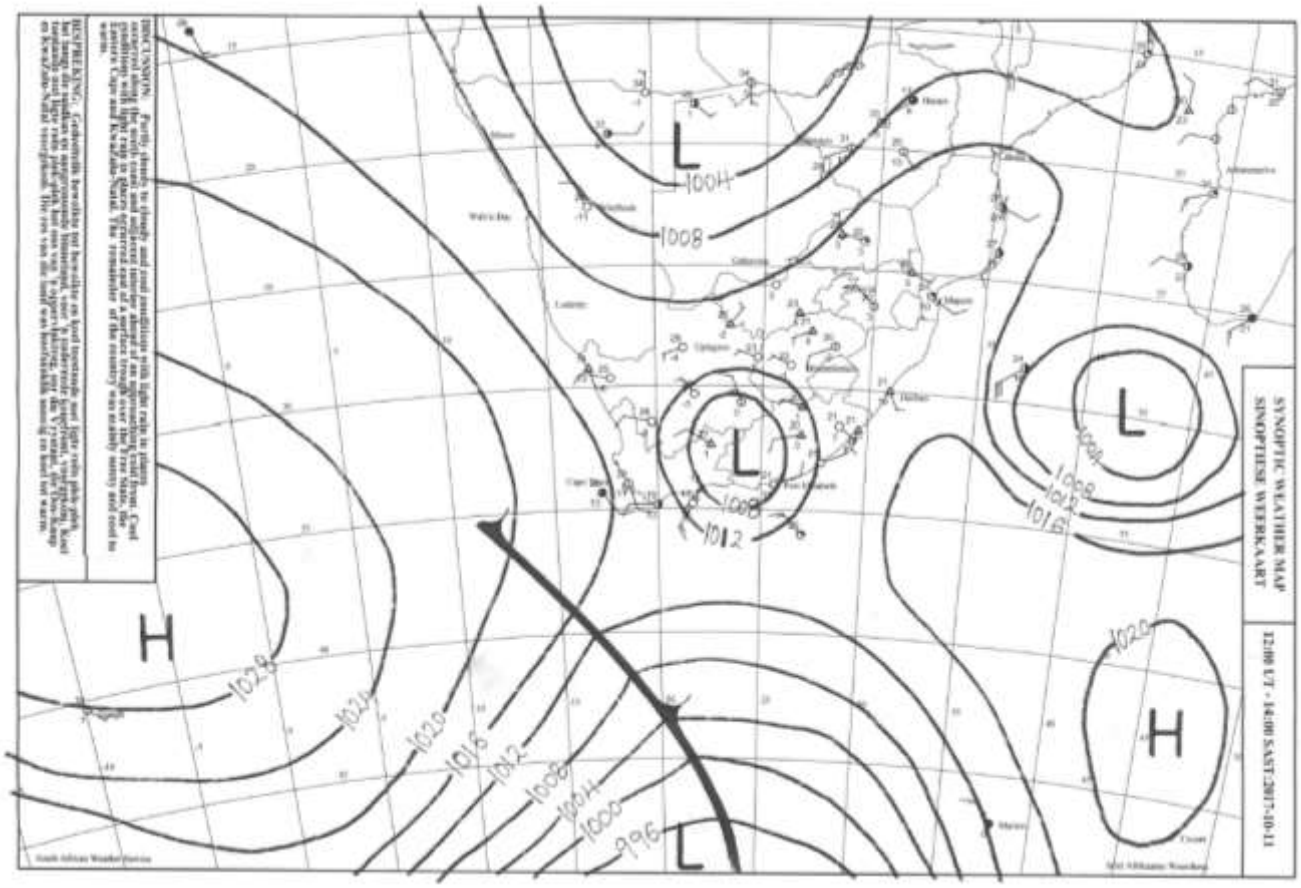


Figure 32: SAWS historical synoptic chart and summary 1400 SAST 11 10 2017

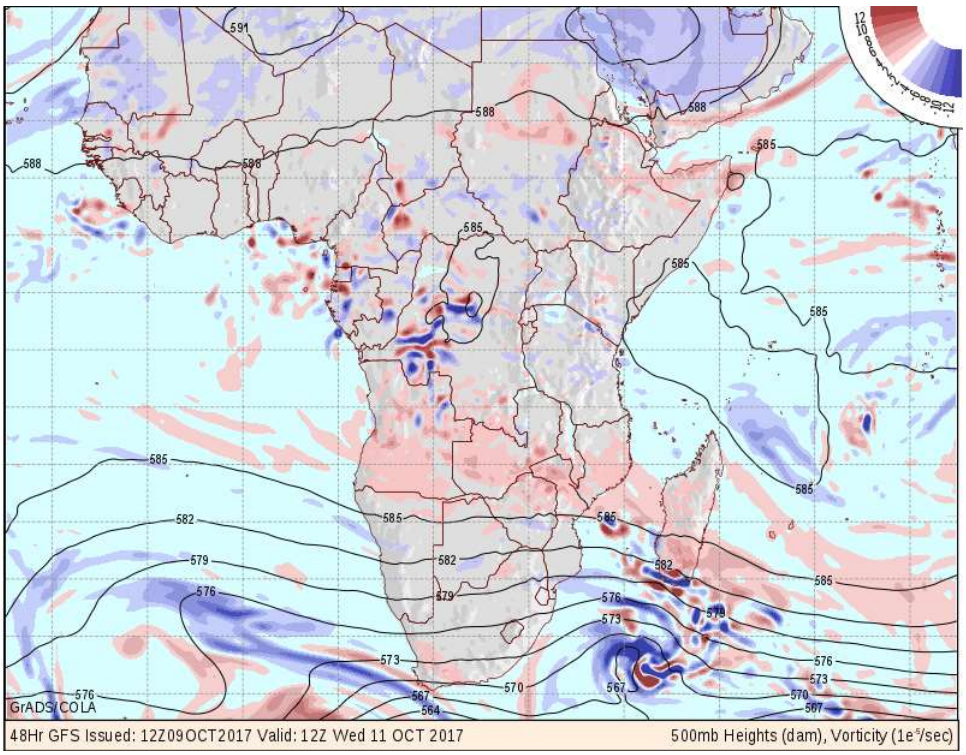


Figure 33: 11 10 2017 12 PM forecast done on 9 10 2017 of 500 hPa geopotential heights and vorticity

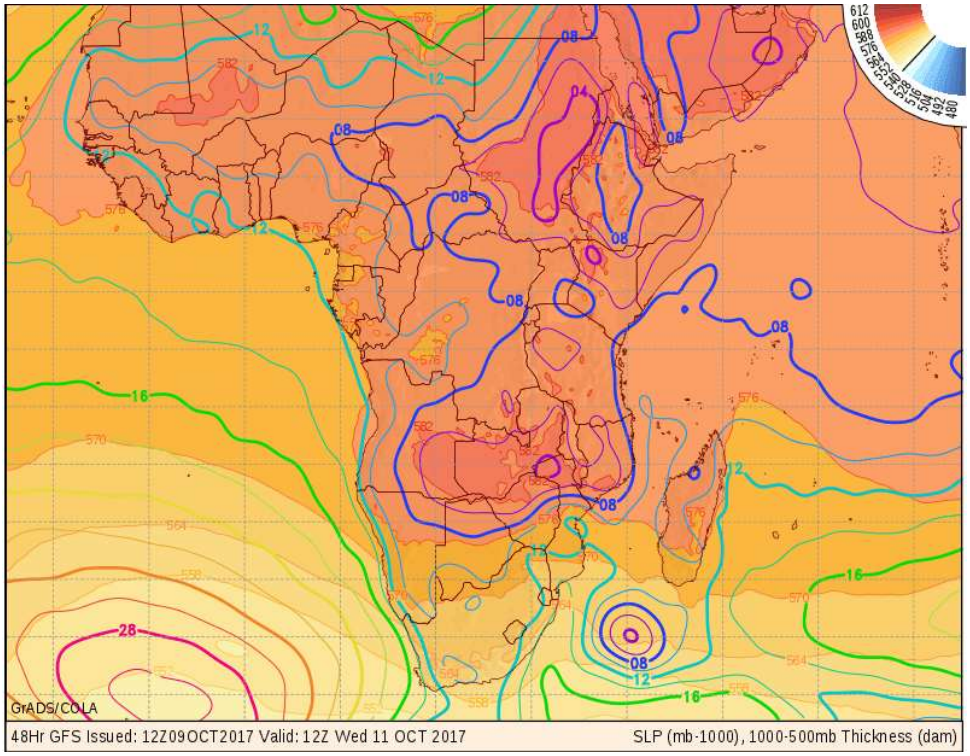


Figure 34: 11 10 2017 12 PM forecast done on 9 10 2017 of surface level pressure. Purple line shows the surface low pressure moving eastwards.

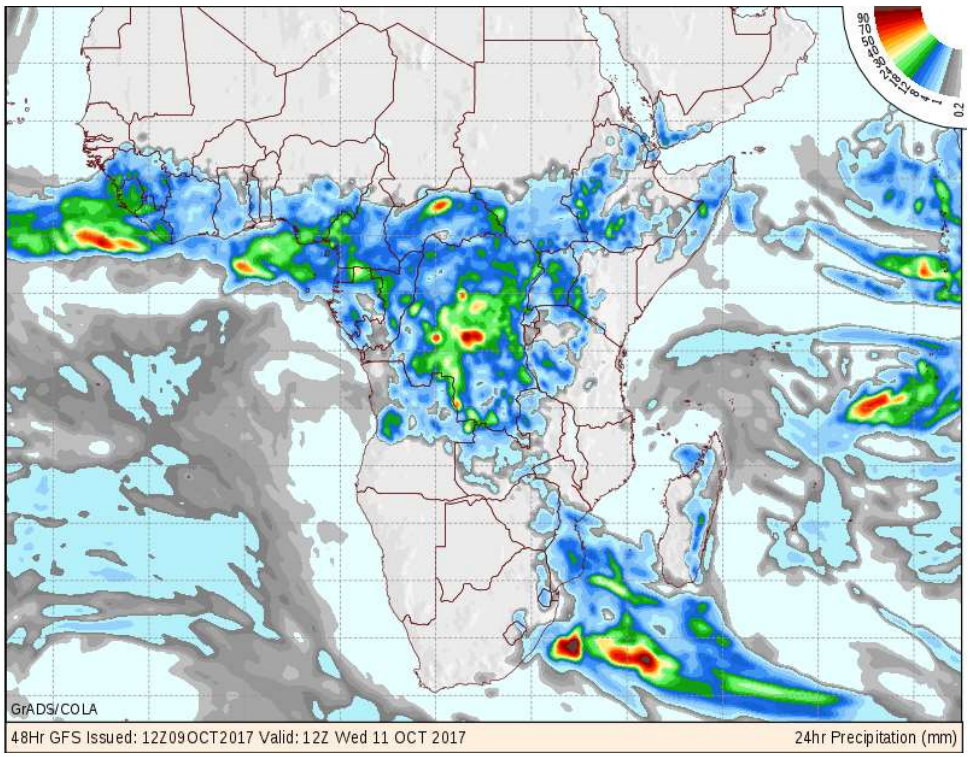


Figure 35: forecasted cumulative precipitation from 10 10 2017 12 PM to 11 10 2017 12 PM on the 9 10 2017.