3.2.3 Yearly Wind Scenarios

Since winds were deemed the single most important driving force in generating the Roberts Bay circulation (see Rescan 2012b), it was useful to complete simulations with different wind regimes to assess how the flushing rate could vary on a year-to-year basis. Although wind data for the summer months were available yearly from 2005 onwards (see Figures 1 to 7 in the Appendix for wind rosettes), simulations were done only for odd years. The rest of the input data (initial temperatures and salinity, freshwater discharges, etc.) were the same as the 2011 simulation. The results for the flushing rates are again shown in Table 3.2-1. All wind scenario simulation resulted in longer flushing rates (i.e., longer residence times) than the 2011 year; the differences were low when considering the transport rate at all depths (maximum of 2.22 days between 2011 and 2007), but increased significantly when considering only the bottom layer (maximum of 10.13 days between 2011 and 2005). The rapid flushing for 2011 is attributed mainly to the higher wind magnitudes found during that year, since stronger winds result in deeper, more intense currents (Gill 1982).

3.2.4 Freshwater Flow Scenarios

The freshwater discharge from the Little Roberts and Glenn outflows were secondary contributors to the circulation within Roberts Bay, but the impact of their variability is difficult to assess simply by looking at the 2011 baseline model run. Given that the total riverine input is not well known for Roberts Bay, and that the values used in the numerical model likely underestimated the true freshwater input to the system, two different scenarios were run through the model where the freshwater flow was doubled and quadrupled. These scenarios highlighted one of the main advantages of numerical modelling, the potential to analyze the sensitivity of one distinct parameter (i.e., freshwater discharge rate) within a complex system.

The resulting flushing times are shown again in Table 3.2-1. Since the general mean circulation in the bay is positive estuarine, the expected response to an increase in freshwater discharge in the southern bay would be a greater seaward density gradient, enhanced flows out of the bay and thus lower flushing times. However, larger flushing times were recorded at all transect depths for both scenarios; relatively minor differences when considering the complete water column depth (< 0.5 day increases), but fairly important when only considering the bottom waters, with a difference of over 10 days between the 2011 baseline and quadruple flow simulations. During the model runs, the increased freshwater input served to lower the water salinity and temperatures in the top 10 m of the water column, hence increasing the stratification and limiting the transfer of wind energy between the surface and deep waters. This in turn led to slightly lower current velocities and changes in circulation patterns, resulting in the lower flushing times within the model.

3.2.5 Wind Direction Scenarios

Another significant difference in the wind data between the 2011 and previous years was the generally more southerly wind directions, particularly in July. Since southerly winds naturally push waters out of the bay, this should contribute to faster flushing rates. To verify the impact each cardinal wind direction has on the Roberts Bay system, four test simulations were initiated where the winds had the same magnitudes as in 2011, but the directions were constantly northern, eastern, southern or western (i.e., direction of 0°, 90°, 180° or 270°). These scenarios, although physically implausible, help to isolate the impact of each wind direction with respect to the bay's flushing. As displayed in Table 3.2-1, the results for flushing times indicate very little difference between north, east or west directions. The northern scenario had slightly lower flushing times, since the wind direction impedes the natural positive-estuarine flow. The southern wind scenario resulted in the lowest flushing times of all simulated runs, with only roughly 10 days for the bottom layer calculation. This result agrees with the hypothesis that the 2011 flushing times in July were faster due to more southerly winds.

4. Summary and Conclusions

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4.1 GENERAL CIRCULATION PATTERN

A 3D hydrodynamic coastal model (MIKE3 by DHI) was used to reproduce the 2011 baseline marine conditions for Roberts Bay as reported in Rescan (2012b). Despite the many simplifying assumptions made during model construction, the simulations were able to reasonably reproduce the two-layered thermohaline structure and current velocities of the bay, with layer delimitations generally within 5 to 10 m of the measured data.

The current depth structures modelled at the ADCP locations differed from what the instrumentation measured, but the velocity magnitudes were of the same order. The emergent circulation pattern in the bay was that of a positive estuarine-type flow with strong seaward flow and lower, more diffuse bottom water landward flow. This is in agreement with the observations detailed in Rescan (2012b). However, predicted current directions varied extensively with wind input, and the circulation pattern sometimes shifted into negative-type flow where the bottom layer had seaward flow and vice versa for the top layer.

4.2 ROBERTS BAY FLUSHING TIMES

The time required by the model to flush all waters from the bay at the Roberts Bay/Melville Sound transect boundary, starting from the complete disappearance of the ice cover on July 4, was computed for the 2011 baseline simulation and several other scenarios. The results are summarized below:

- For the 2011 baseline simulation, it took less than a week for a total volume of water equivalent to Roberts Bay to transport out into Melville Sound. This time increased to nearly 18 days when only calculating from 30 m depth to the water bottom.
- The minimum flushing times were obtained by forcing all winds to be from the southern direction, thereby enhancing all flow out of Roberts Bay into Melville Sound. This resulted in a flushing time for the bay of slightly above 5 days when considering the complete water column, and a time of approximately 10 days when calculating from 30 m to the water bottom.
- The maximum flushing times using realistic winds were obtained by running the 2011 simulation with 2007 winds, taking nearly 9 days to flush the bay out over the complete water column, and more than 26 days when considering the 30 m to bottom layer.
- The absolute maximum flushing for the 30 m to bottom section resulted from the quadruple freshwater outflow scenario for 2011.
- Overall, stronger winds and more southerly wind directions lowered the flushing times of the bay, while increased flushing times resulted from greater freshwater input and north-westerly winds.

In summary, a conservative estimate for the flushing time of the bottom waters (i.e., 30 m +) of Roberts Bay at the onset of summer 2011 is approximately 3 weeks, and when considering various circulation scenarios the maximum flushing time is estimated at nearly a month. Thus, it is surmised from the modelling results that Roberts Bay will be effectively flushed multiple times with Melville Sound waters during the f-month long summer season.

References

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References

Definitions of the acronyms and abbreviations used in this reference list can be found in the Glossary and Abbreviations section.

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Appendix 1

Monthly Wind Roses at Roberts Bay, Doris North Project, July to October, 2005-2011

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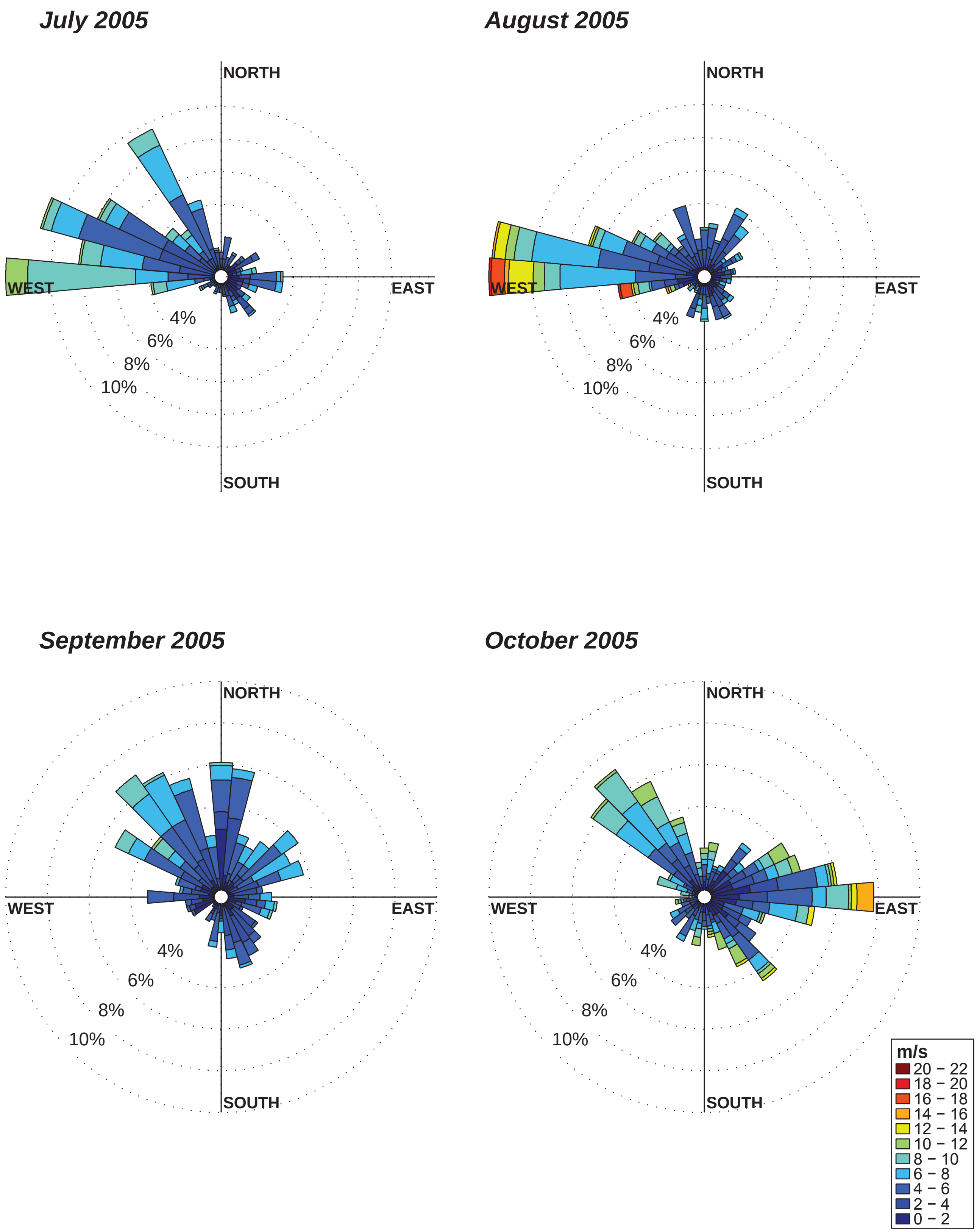

Figure 1

2005 Windroses

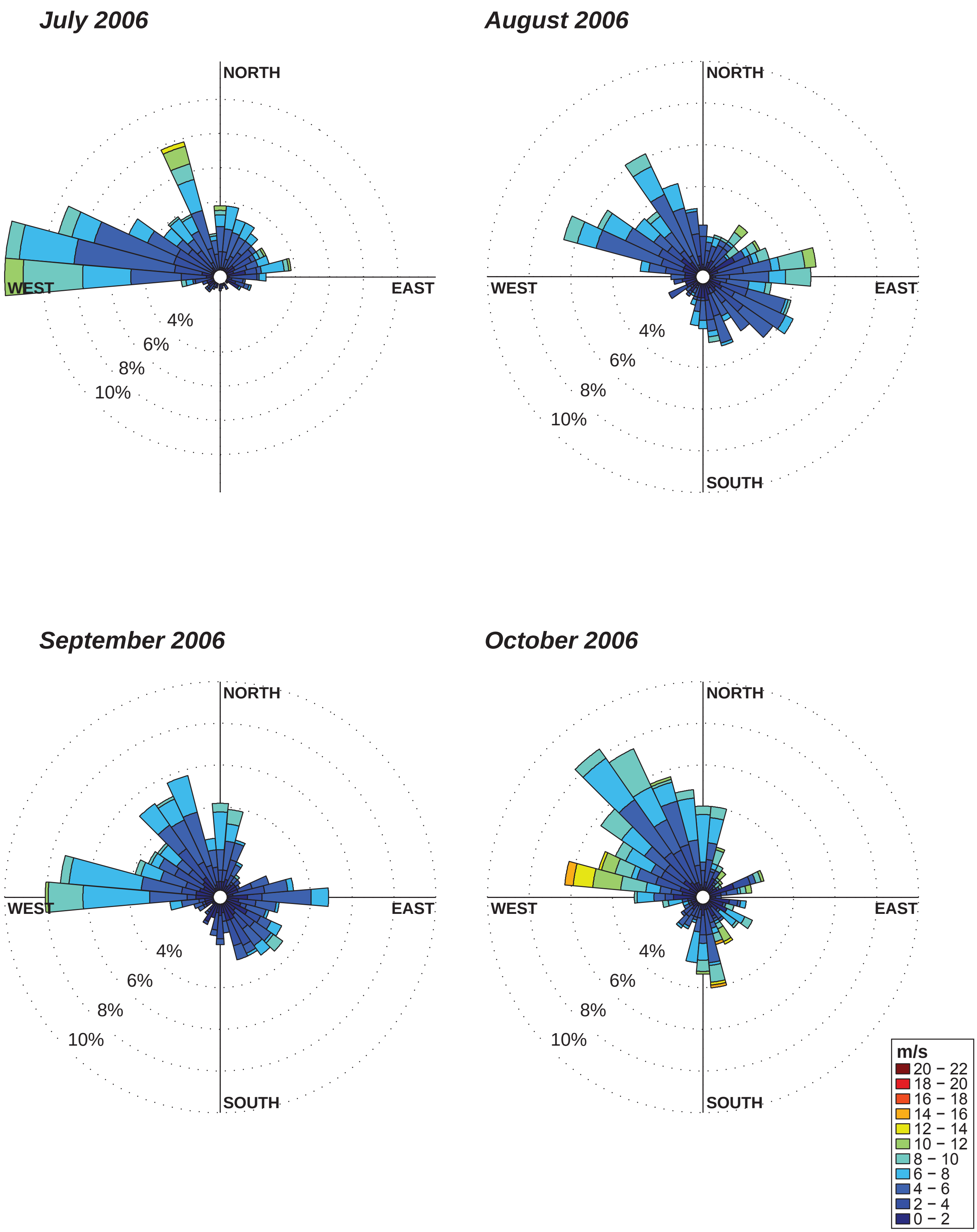

Figure 2

2006 Windroses

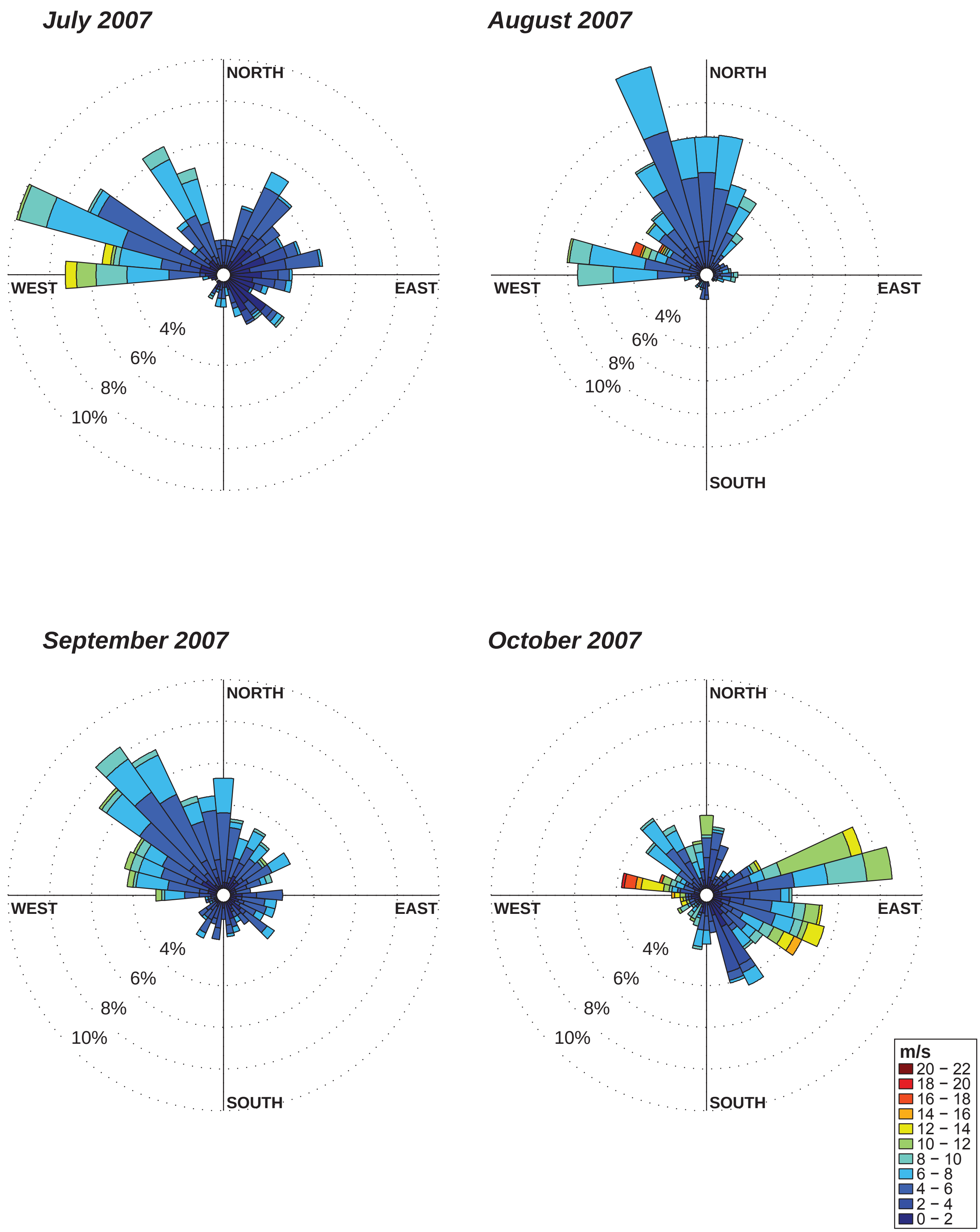

Figure 3

2007 Windroses

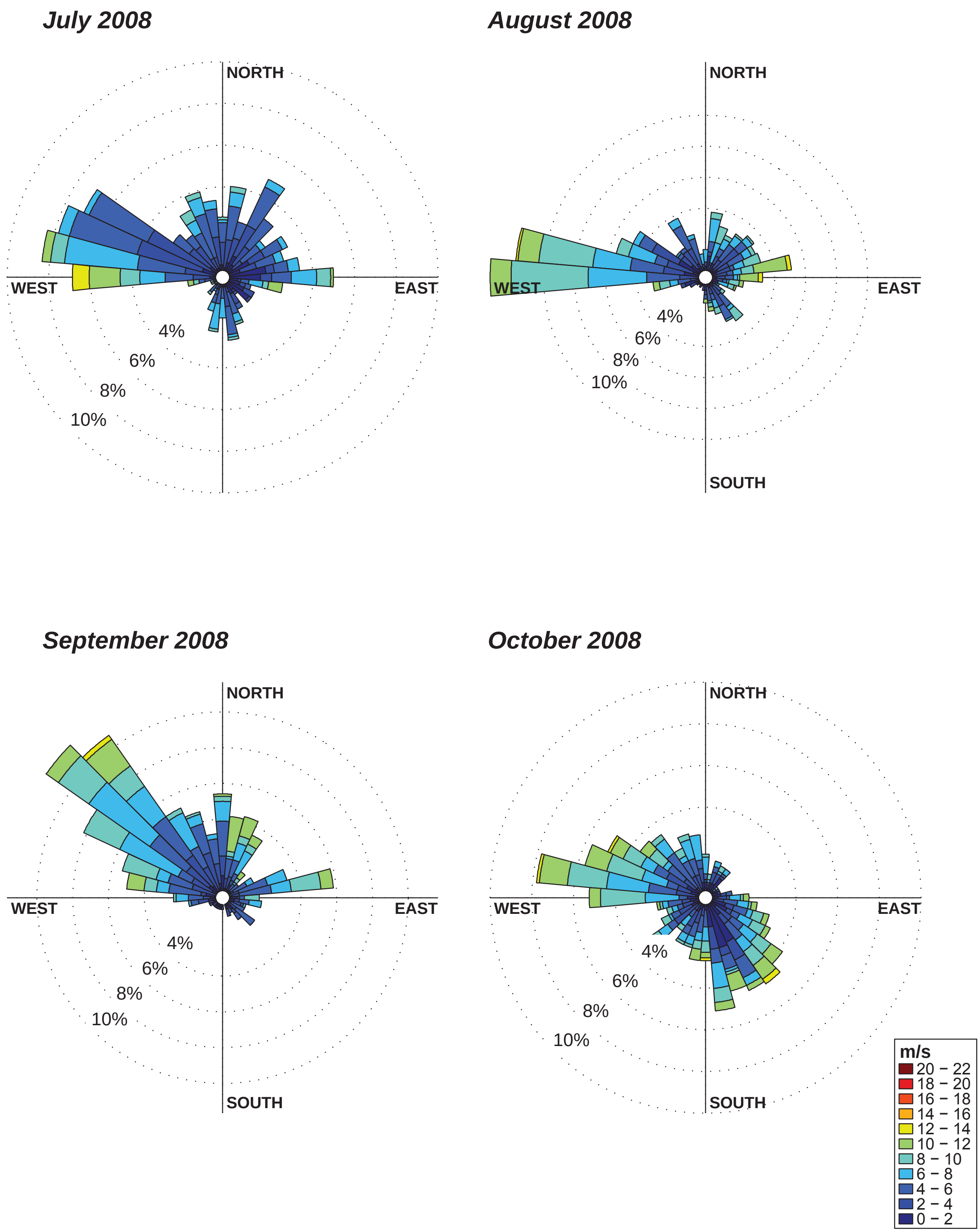

Figure 4

2008 Windroses

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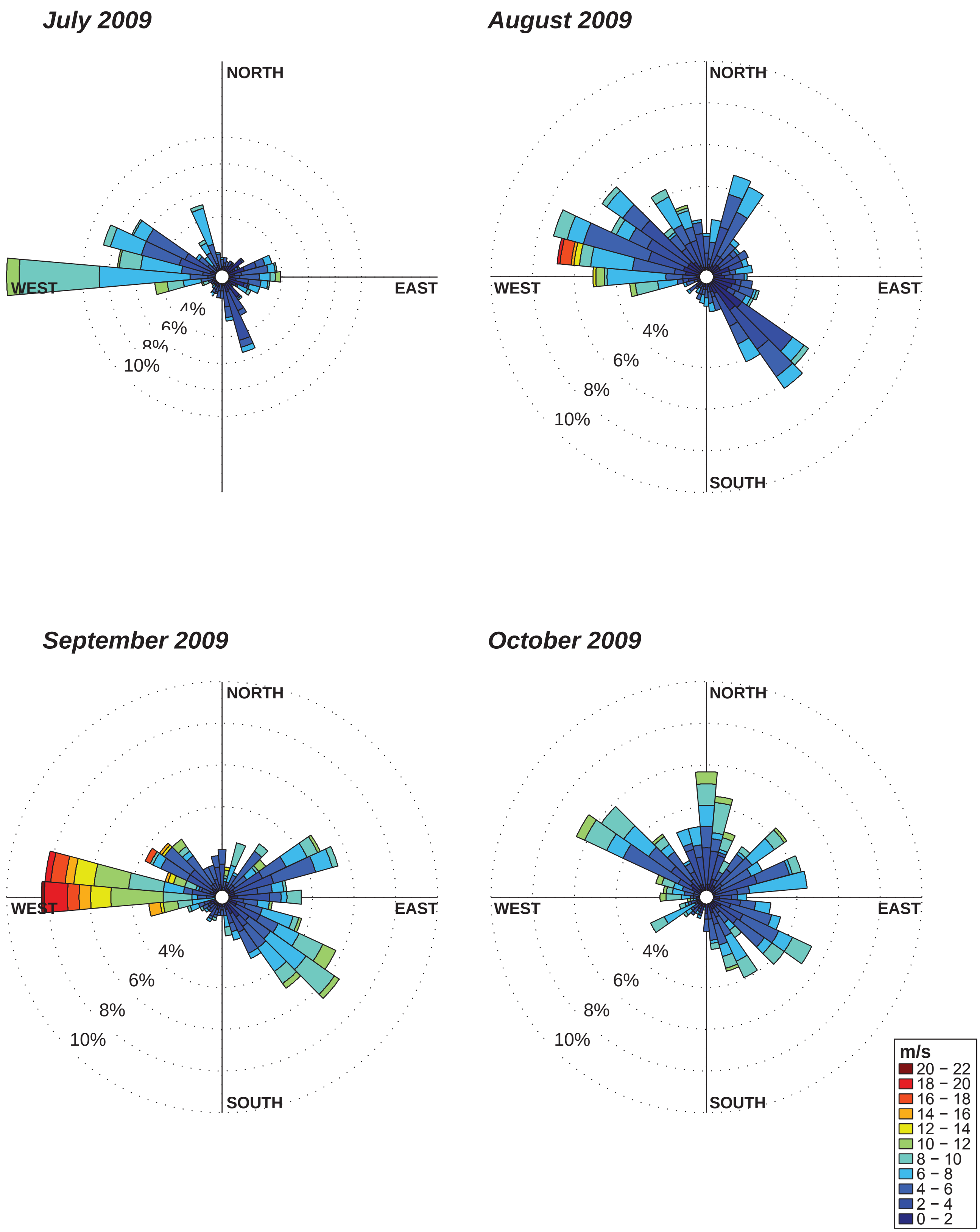
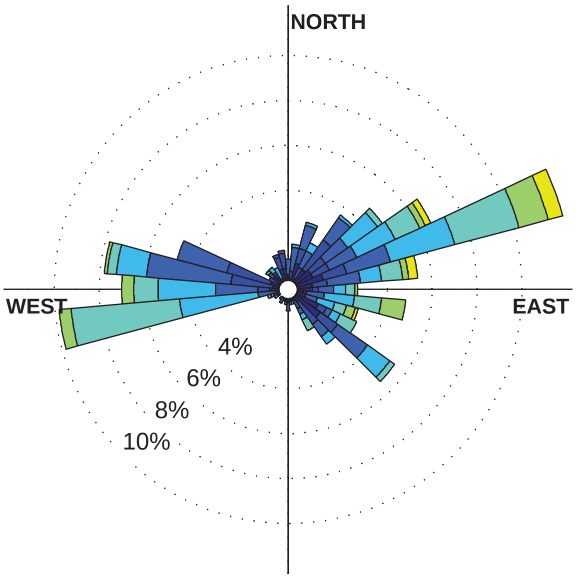


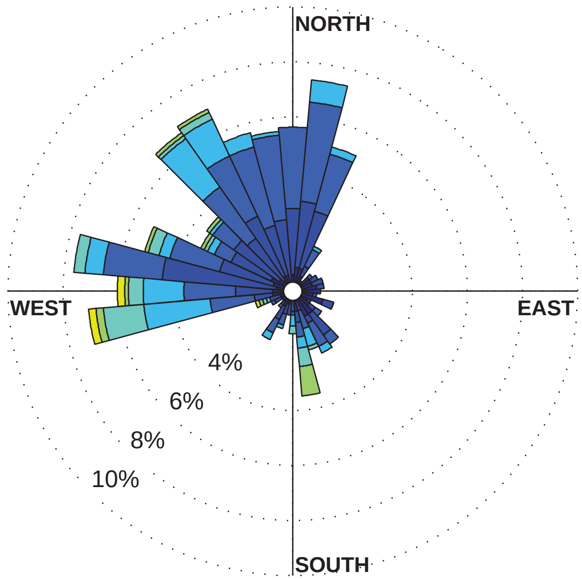
Figure 5

2009 Windroses

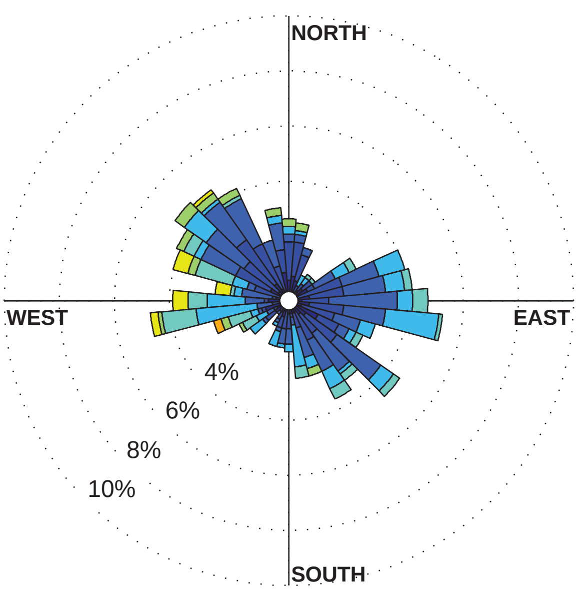
July 2010



August 2010



September 2010



October 2010

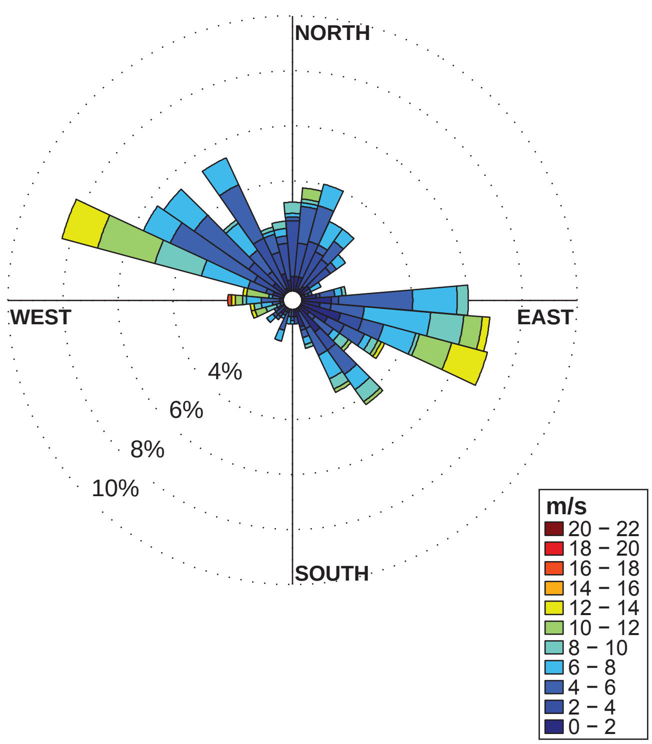


Figure 6

2010 Windroses

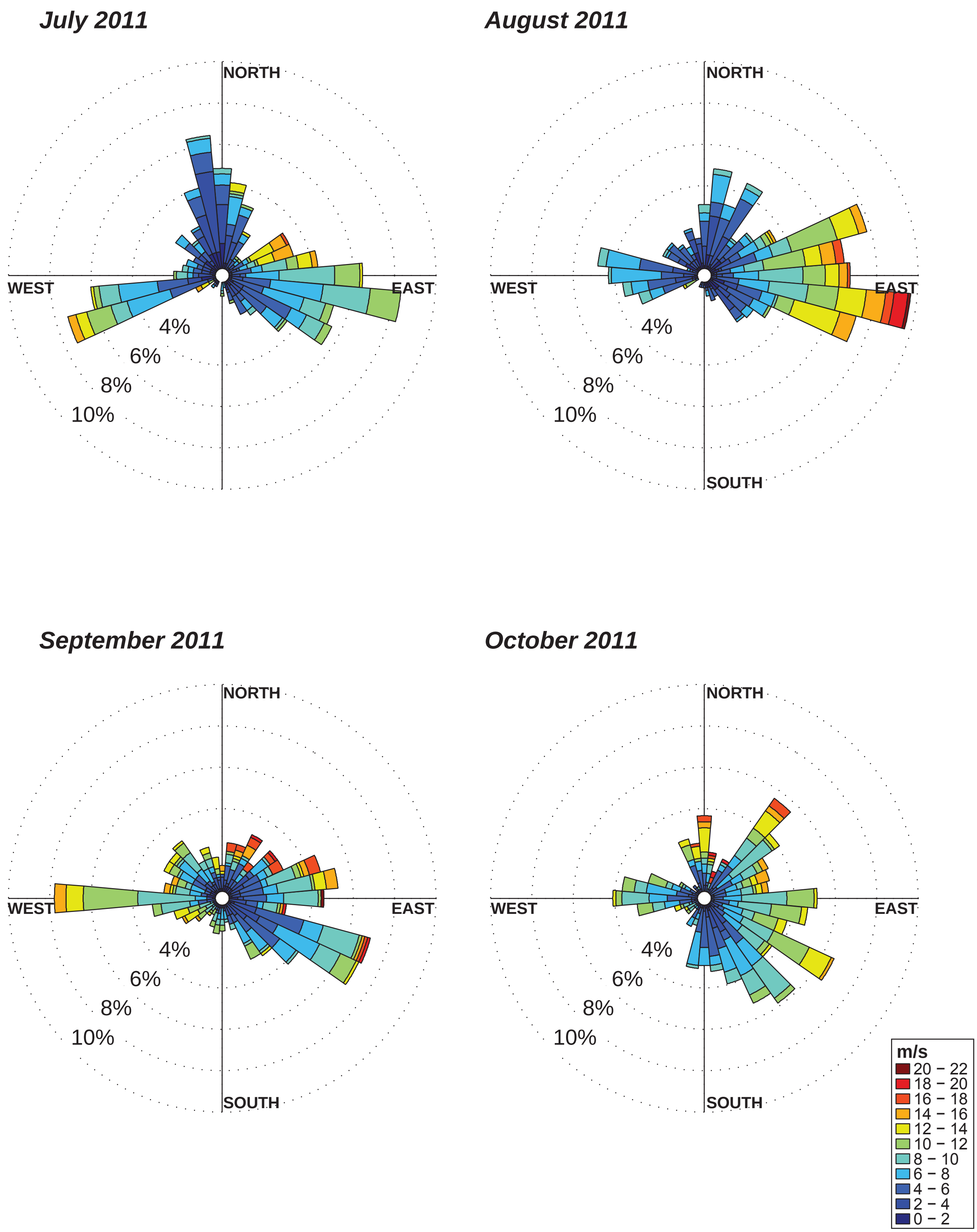


Figure 7

2011 Windroses

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