Identification of Sea Breezes, their Climatic Trends and Causation, with Application to the Adelaide Coast

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Abstract

Nearshore processes along the sandy beaches of Adelaide are driven by the prevailing wind and waves. While the narrow entrance of Gulf St. Vincent and the shallow waters attenuate the ocean swell waves, the locally generated southerly to south-westerly waves are behind the net northward littoral drift transport. An important factor in the generation of local waves are the sea breezes, which for Gulf St Vincent result from a combination of a southerly ocean breeze and westerly gulf breezes, and a key question in this time when the climate is said to be changing is whether there is evidence that these sea breezes are changing.

This study, therefore, investigates the existence of long-term changes to the gulf breeze; hereafter referred to as the sea breeze, over the period of August 1955 to June 2008.

In the study of the local climate a set of criteria were developed to define and identify the sea breeze days on which the locally generated coastal winds are generally dominant in the afternoon. Considering the limitation of meteorological observations, the criteria employed the three-hourly near surface data, the 12-hourly upper air levels recorded data, and the surface temperatures of Gulf St. Vincent, provided by Advanced High Resolution Radiometer (AVHRR).

Applying the methods, the period of study is divided into sea breeze and non-sea breeze days, where the characteristic afternoon wind in both categories is analysed. Although the annual percentage of observed sea breeze cases does not show any significant change over the period of the study, the results have demonstrated the presence of an increasing trend in the intensity of afternoon winds, more evidently for the selected sea breeze days.

Through regression analysis of the results, the rise of the southerly component of the wind has been found to have a strong correlation with the surface temperature of the
land, whereas the growth of the westerly component was not correlated with any local climate drivers.

Following this important result, the study then went on to determine what might be driving this change. As the importance of urbanization on the climate of wind has been extensively studied by previous researchers, the growth of the Adelaide metropolitan area was conjectured to affect the wind climate at the planetary boundary layer.

A next-generation mesoscale numerical model, Weather Research and Forecasting (WRF), was employed to simulate the climate of the area with and without the metropolitan area of Adelaide, where the city was replaced by the native vegetation of the land. From the simulations it appears that the westerly components of the winds are strongly affected by changes to the nature of the land, due to a combination of changes to the surface roughness length and modification of the surface heat budget components.

The main findings of the statistical and numerical study of the wind climate of Adelaide are:

1. The wind climate in and around Gulf St. Vincent has shown a statistically significant change over the last 50 years.

2. While there has been no significant change in the number of sea breeze days, the current wind climate has significantly higher wind speeds more evidently on sea breeze days. This is likely to have an important effect on the coast, particularly if the trend continues.

3. Through the component-wise analysis of wind, the change in the intensity of south-north component of wind intensity was found to be correlated to the increasing trend of land surface temperature. This is likely to explain one of the key drivers of the change in wind climate.
4. A numerical modelling exercise demonstrated the importance of the growth of the metropolitan area of Adelaide with the change in surface roughness and the change to the surface energy budget being two key elements of the change. In the end, there is still a need for future study to examine the possible effects of prolonged changes of wind characteristics on the dynamics of the shoreline, particularly in regard to the littoral sediment transport system.
Statement of Originality

I, Zahra Pazandeh Masouleh certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name, in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission in my name, for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree.

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Signature:

Date:
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# List of Abbreviation

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<thead>
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<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>AAO</td>
<td>Antarctic Oscillation</td>
</tr>
<tr>
<td>ACST</td>
<td>Australian Central Standard Time</td>
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<tr>
<td>AFWA</td>
<td>Air Force Weather Agency</td>
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<tr>
<td>AHD</td>
<td>Australian Height Datum</td>
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<tr>
<td>AOI</td>
<td>Antarctic Oscillation Indices</td>
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<tr>
<td>ARW</td>
<td>Advanced Research WRF</td>
</tr>
<tr>
<td>AVHRR</td>
<td>Advanced Very High Resolution Radiometer</td>
</tr>
<tr>
<td>CBD</td>
<td>Central Business District</td>
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<tr>
<td>CGA</td>
<td>Synchrotac Cup Anemometer</td>
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<tr>
<td>CSIRO</td>
<td>Commonwealth Scientific and Industrial Research Organisation</td>
</tr>
<tr>
<td>CTL</td>
<td>Control Run</td>
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<tr>
<td>DST</td>
<td>Daylight Saving Time</td>
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<tr>
<td>ENSO</td>
<td>El Niño Southern Oscillation</td>
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<tr>
<td>ETA</td>
<td>Eta Model</td>
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<tr>
<td>FAA</td>
<td>Federal Aviation Administration</td>
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<td>FSL</td>
<td>Forecast System Laboratory</td>
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<tr>
<td>GCM</td>
<td>General Circulation Models</td>
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<td>GDAS</td>
<td>Global Data Assimilation System</td>
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<tr>
<td>GTS</td>
<td>Global Telecommunications System</td>
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<tr>
<td>IOA</td>
<td>Index Of Agreement</td>
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<tr>
<td>IOD</td>
<td>Indian Ocean Dipole</td>
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<tr>
<td>LH</td>
<td>Latent Heat</td>
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<tr>
<td>LW</td>
<td>Long Wave radiation</td>
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<tr>
<td>MB</td>
<td>Mean Biass Error</td>
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<tr>
<td>MM5</td>
<td>PSU/NCAR mesoscale model</td>
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<tr>
<td>MO</td>
<td>Monin–Obukhov similarity theory</td>
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<tr>
<td>NCAR</td>
<td>National Center for Atmospheric Research</td>
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<tr>
<td>NCEP</td>
<td>National Center for Environmental Prediction</td>
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<tr>
<td>NCEP FNL</td>
<td>global reanalysis datasets (final data analysis) from the US National Centers for Environmental Prediction</td>
</tr>
<tr>
<td>NESL</td>
<td>parallel language developed at Carnegie Mellon</td>
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<tr>
<td>NMM</td>
<td>Non-hydrostatic Mesoscale Model</td>
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<tr>
<td>NOAA</td>
<td>National Oceanic and Atmospheric Administration</td>
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<tr>
<td>NRMSE</td>
<td>Normalized root mean square error</td>
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<tr>
<td>NTV</td>
<td>Native Vegetation (model)</td>
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<tr>
<td>NVIS</td>
<td>National Vegetation Information System</td>
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<tr>
<td>Abbreviation</td>
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<tr>
<td>PBL</td>
<td>Planetary Boundary Layer</td>
</tr>
<tr>
<td>pchip</td>
<td>Piecewise Cubic Hermite Interpolating Polynomial</td>
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<tr>
<td>PTA</td>
<td>Dines Pressure Tube Anemometer</td>
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<tr>
<td>Qv</td>
<td>mixing ratio for water vapour</td>
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<tr>
<td>RAAF</td>
<td>Royal Australian Air Force</td>
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<tr>
<td>RCM</td>
<td>Regional Climate Models</td>
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<tr>
<td>RMSD</td>
<td>Root Mean Square Difference</td>
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<td>RMSE</td>
<td>Root Mean Square Error</td>
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<td>RSM</td>
<td>Reynolds Stress equation Model</td>
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<td>SH</td>
<td>Sensible Heat</td>
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<td>SLP</td>
<td>Sea-Level Pressure</td>
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<td>SOI</td>
<td>Southern Oscillation Index</td>
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<td>SW</td>
<td>Short Wave radiation</td>
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<tr>
<td>UCI</td>
<td>Urban Cool Island</td>
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<td>UHI</td>
<td>Urban Heat Island</td>
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<td>USGS</td>
<td>U.S. Geological Survey</td>
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<td>WMP</td>
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<td>WPS</td>
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<td>WRF</td>
<td>Weather Research and Forecasting</td>
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