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

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BENG (CIVIL & STRUCTURAL), MSCENG (Coastal)

A THESIS SUBMITTED FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

THE UNIVERSITY of ADELAIDE

SCHOOL OF CIVIL, ENVIRONMENTAL AND MINING ENGINEERING

July 2015

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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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Acknowledgement

I would like to express my deep and sincere gratitude to my supervisors: Professor David Walker and Professor John Crowther, for their valuable guidance, consistent encouragement, understanding, patience, and most importantly, their friendship throughout the research work.

I am extremely grateful to my main supervisor Prof. David Walker, for his guidance and all the useful discussions and brainstorming sessions, especially during the difficult conceptual development stage. His deep insights helped me at various stages of my research. I also remain indebted for his understanding and support during my maternity leave. My sincere gratitude is reserved for Prof. John Crowther for his invaluable insights and suggestions. I really appreciate his willingness to meet me at short notice every time and going through several drafts of my thesis. I remain amazed that despite his busy schedule, he was able to go through the final draft of my thesis and meet me in less than a week with comments and suggestions on almost every page. He is an inspiration. I also acknowledge the contribution of Dr. Murray Townsend to my thesis and his support as a member of my PhD supervision panel is highly appreciated. I thank Mr. Darren Ray, senior meteorologist at South Australian Regional Climate Services Centre of Bureau of Meteorology for his supports and helps with meteorological data.

Sincere thanks are extended to the former computing officer, Dr. Stephen Carr and the school administrative staff, for their help.

I wish to thank my fellow postgraduates in the School of Civil, Environmental and Mining Engineering for their assistance and friendship. Special thanks to my very good friends Li Li, Jaya and Nimasha, who have made this journey so much more enjoyable. I owe a lot to my parents, who encouraged and helped me at every stage of my personal and academic life, and longed to see this achievement come true. Lastly, I would like to dedicate this thesis to my precious daughter, Aida and my loving, supportive, encouraging, and patient husband Arash Asadi whose faithful support through this Ph.D. is so appreciated.

List of Abbreviation

AAO	Antarctic Oscillation
ACST	Australian Central Standard Time
AFWA	Air Force Weather Agency
AHD	Australian Height Datum
AOI	Antarctic Oscillation Indices
ARW	Advanced Research WRF
AVHRR	Advanced Very High Resolution Radiometer
CBD	Central Business District
CGA	Synchrotac Cup Anemometer
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CTL	Control Run
DST	Daylight Saving Time
ENSO	El Niño Southern Oscillation
ETA	Eta Model
FAA	Federal Aviation Administration
FSL	Forecast System Laboratory
GCM	General Circulation Models
GDAS	Global Data Assimilation System
GTS	Global Telecommunications System
IOA	Index Of Agreement
IOD	Indian Ocean Dipole
LH	Latent Heat
LW	Long Wave radiation
MB	Mean Biass Error
MM5	PSU/NCAR mesoscale model
MO	Monin–Obukhov similarity theory
NCAR	National Center for Atmospheric Research
NCEP	National Center for Environmental Prediction
NCEP FNL	global reanalysis datasets (final data analysis) from the US National Centers for Environmental Prediction
NESL	parallel language developed at Carnegie Mellon
NMM	Non-hydrostatic Mesoscale Model
NOAA	National Oceanic and Atmospheric Administration
NRMSE	Normalized root mean square error
NTV	Native Vegetation (model)
NVIS	National Vegetation Information System

PBL	Planetary Boundary Layer
pchip	Piecewise Cubic Hermite Interpolating Polynomial
PTA	Dines Pressure Tube Anemometer
Qv	mixing ratio for water vapour
RAAF	Royal Australian Air Force
RCM	Regional Climate Models
RMSD	Root Mean Square Difference
RMSE	Root Mean Square Error
RSM	Reynolds Stress equation Model
SH	Sensible Heat
SLP	Sea-Level Pressure
SOI	Southern Oscillation Index
SW	Short Wave radiation
UCI	Urban Cool Island
UHI	Urban Heat Island
USGS	U.S. Geological Survey
WMP	Warmer Months Prediction
WPS	WRF pre-processing system
WRF	Weather Research and Forecasting
WSM3	WRF Single Moment 3 classes