Weather patterns for sailing in Weymouth Bay & Portland Harbour:

Analysis for the 2012 Olympic Games

Louisa Ververs

Institute for Atmospheric & Climate Science (IACETH)

ETH Zürich

verversl@student.ethz.ch

Supervisors:
Dr. Natascha Kljun, Swansea University
Dr. Jürg Schmidli, IACETH
Dr. Michael Sprenger, IACETH
Prof. Christoph Schär, IACETH

A proposal for a thesis leading to the degree of

Master of Sciences

April 2011

Summary   In sailing, weather is the most important factor determining a safe passage, an enjoyable day or a successful race. As local weather is crucial in developing a racing strategy for sailing, studying weather patterns is an essential part of preparation for a race. To eliminate the advantage that home competitors have, i.e. local knowledge, foreign competitors often rely on meteorologists for long-term, regional weather analysis to determine specific, local weather patterns.

Apart from sailing events, coastal environments are interesting because of several unique weather processes that occur there. Several factors are involved, such as synoptic, topographic and thermal forcing, which lead to thermal and moisture gradients. These gradients, in turn, give rise to local circulations. Every location has its own unique combination of forcing-types and thus, an unique local circulation and associated weather patterns. Knowledge of these local weather patterns is valuable information in competitive sailing. Therefore, often, sailing teams do not disclose any findings to opposing teams. This is also the case for the 2012 London Olympic Games, for which Weymouth Bay & Portland Harbour in South England will host the sailing events.

This thesis aims to broaden the limited knowledge of local weather patterns in the Weymouth & Portland racing area. The first step will be a climatological study aimed at finding local wind patterns, persistence and variability. The second step involves selecting three case studies, such as the most frequent occurring phenomena, which will then be simulated using the Weather Research and Forecasting model, which is a mesoscale numerical weather prediction system. Finally, our findings will be verified by observations and local knowledge interviews. The result will be an in-depth understanding of local weather patterns, which the Swiss Olympic Sailing Team can use to build their racing strategy for the 2012 Olympic Games.

Contents

1 Background

A recent press release of the British Olympic Sailing Team states that BAE Systems, a large defense company in England, has worked together with British sailors over a five year period, using military technology and a £1.5 million investment (Mortimer, 2010). The result is an extremely detailed weather prediction system for the 2012 Olympic Games that can forecast detailed changes in the surface winds; but only accessible by British Olympic sailors.

It is not unusual for sailing teams to keep their meteorological data 'top-secret', as Powell (1993) already encountered in 1991 when he acted as the U.S. Sailing Team meteorologist for the Pan American Games. In competitive sailing, knowledge of local wind characteristics is used to determine a racing strategy. Therefore studying weather patterns is an essential part of preparation for a race. A general belief is that sailors sailing in their local waters have a 'home-advantage'. To eliminate this advantage, foreign competitors often rely on meteorologists for long-term, regional weather analysis to determine specific, local weather patterns.

Apart from sailing events, coastal environments are interesting to atmospheric scientists because of several unique weather processes that occur there. The wide variety of coastal weather is a result of the coastline - a discontinuity of surface roughness, albedo and availability of water as land transitions into water, thus influencing the surface energy balance and the land-sea circulation - as well as its combination with synoptic-scale weather conditions. These complex interactions result in dynamical processes, such as thermal and moisture gradients, which give rise to secondary circulations in the narrow zone along the coast (Nuss, 2003). These secondary circulations produce the local weather patterns and determine local wind behaviour, which is the valuable information that can assist in a gold medal victory for sailors.

For sailing, the most important meteorological factor is wind and especially its small-scale characteristics. For certain areas or situations, these small-scale characteristics of coastal winds are known from previous studies. An example is the study by Arritt (1993), where he found that large-scale flow, or synoptic winds, influenced the small-scale wind characteristics. When the synoptic wind was directed offshore, the local coastal wind velocity was much stronger than the velocity of the local wind that developed with onshore synoptic wind. He was able to draw this conclusion from

31 numerical simulations because, although each area has unique circumstances which result in unique local flows, underlying mechanisms are similar. Two of these wind mechanisms that occur frequently are the sea breeze and the low-level jet.

A sea breeze (see Fig. 1) is a result of thermal forcing that creates a land-sea temperature gradient. During the day, the air above land heats up whilst the air above the sea remains relatively cold. Consequently, a pressure gradient and an onshore wind develops. For many sailing venues, sea breezes are the most dominant phenomena (Powell, 1993; Powell, 1998; Li, 2008), but it does not explain all local weather phenomena. For the 2000 Olympic Games in Sydney, the sea breeze was not a persistent feature, yet this mechanism was used in combination with the synoptic wind to get an appreciation of the local wind characteristics (Connor and Spark, 2004). It follows that, apart from thermal forcing, other factors such as synoptic forcing or topographic forcing play an important role too.
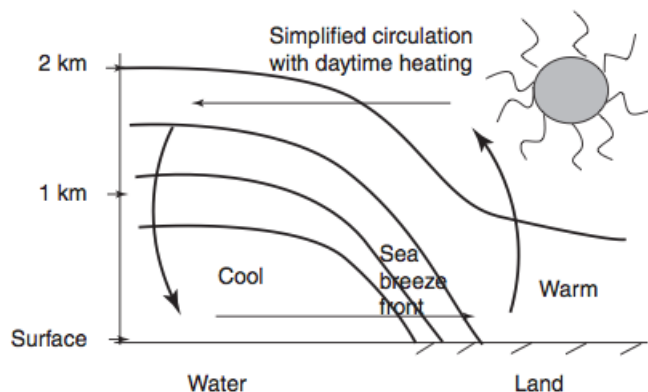

Figure 1: Sea-breeze mechanism (Nuss, 2003)

A low-level jet is a summertime coastal circulation resulting from a strong low-level temperature inversion combined with coastal mountains (Nuss, 2003) and is best illustrated by Fig 2. Similar to the sea breeze, the air above the land has been warmed while the air above the ocean has remained relatively cold. Hence above the ocean lies a cool, well-mixed, marine boundary layer. On top of this marine boundary layer lies a capping inversion (MetEd, 2004) and its isentropes slope downward toward the coast. At the coast the isentropes are nearly vertical, which is a result from the juxtaposition of the cool marine boundary layer with warmer air over land. Thus, at the coast the
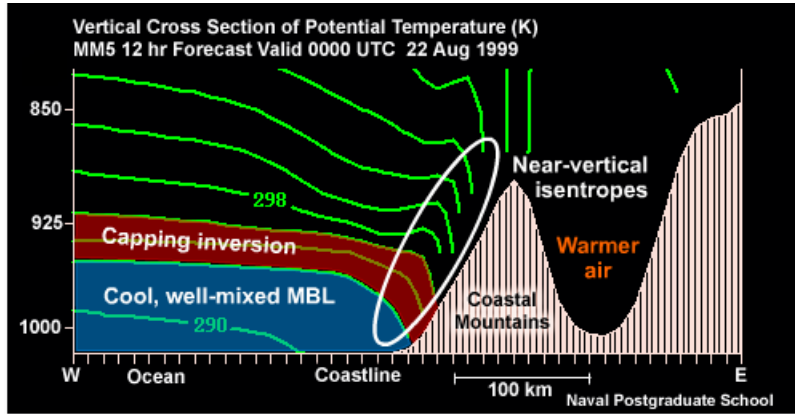
Figure 2: Low-level Jet mechanism (MetEd, 2004)

temperature gradient reaches a maximum, which corresponds to a maximum in the pressure gradient. The maximum pressure gradient has an increasing effect on the low-level wind. Instead of an onshore wind developing, inland flow is blocked by coastal mountains and deflected parallel to the coastline. The result is a fast-flowing wind close to the surface, called a low-level jet.

Applying the concepts of coastal meteorology to a specific racing venue is a crucial step in understanding local weather patterns. This is what BAE Systems engineers have done in their analysis for the upcoming Olympic Games. Racing will take place from the 29th of July till the 11th of August, but preparations of the sailing teams - and their meteorologists - are in progress already.

The sailing events of the 2012 London Olympic Games will be hosted by Weymouth Bay & Portland harbour, situated on the southern coast of England (see Fig. 3).

The only 'public' study of local weather patterns in the Weymouth & Portland region, is a Master thesis written by Magnus Baltscheffsky at Uppsala University in 2010. Baltscheffsky (2010) investigates wind characteristics using the Weather Research and Forecasting (WRF) model. The WRF model is a mesoscale numerical weather prediction system developed for forecasting and research and is capable of running at high spatial resolution. Baltscheffsky used the WRF model to perform dynamical downscaling (obtaining high-resolution information form coarse-resolution data) of analysis data. Evaluation with observations shows that this method is skillful in providing new information at smaller scales from existing meteorological data fields.
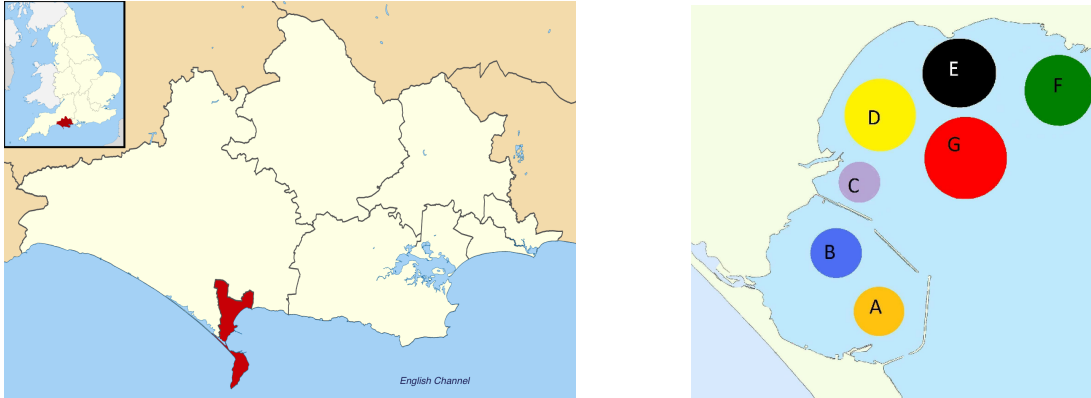
Figure 3: Left: Weymouth Bay & Portland Harbour. Right: Expected racing areas (RYA, 2011)

Running his model over just two months, Baltscheffsky (2010) found indication of an infrequent occurrence of a low-level jet as a result of inertial oscillation in the flow and sustained by a strong baroclinicity over the English Channel. Furthermore, he was able to draw general conclusions of the local wind change given a southwesterly synoptical-scale flow. When there is southwesterly flow, the wind increases and converges around 225-260 degrees in the afternoon. Additionally, on days with a synoptic flow from north of 260 degrees, there is a general backing of wind direction whilst a synoptic flow from south of 260 degrees generally leads to a veering of the wind direction.

However, weather is variable and can change completely in a short period of time, thus a more detailed analysis is desired by the competitors (Li, 2008) Particularly, analysis focussed on the time period when races are scheduled is essential as well as a more specific analysis of synoptic flow situations. Finding this information will give a better understanding of weather patterns and wind characteristics specific to Weymouth Bay & Portland Harbour. This will provide the Olympic athletes with in-depth knowledge to develop racing strategies and, in addition, will aid sailors in recognizing weather patterns as they occur, so that tactics can be adjusted during a race and the potential for success is maximized.

5

2 Objectives

As the WRF model setup by Baltscheffsky (2010) has proven to be valuable, this is a good stepping-stone for further studies for the upcoming Olympic Games. We aim to build this knowledge to provide the Swiss Olympic Sailing Team with a better understanding of local weather patterns in Weymouth Bay & Portland Harbour. To do so, we will research the following questions:

- What are the most frequent occurring weather situations in the Weymouth area in July & August?

- Which coastal circulations occur and how do these develop?

- Are the model findings coherent with local knowledge?

To answer these questions, the work to be done for this project can be divided in four main tasks:

- A climatological study of the last five years focussing on wind patterns, persistence and variability

- Verify findings with knowledge from local meteorologists and sailors

- Investigate three frequent occurring situations by WRF numerical simulation

- Do sensitivity analysis of the physics schemes used in the WRF Model set-up

3 Data & Methods

3.1 Climatological study

An extensive, long-term and regional study of the climatology - focussing on the last 5 years in the Weymouth & Portland region - will be the first step in giving Swiss sailors specific knowledge equivalent to the 'home-advantage' of local sailors. We will use statistical tools to analyse wind patterns, persistence and variability in the racing area. To determine which statistical analysis will be appropriate, the formatting and structure of the data must be studied first.

The data that will be used in this section is analysis data from the UK Met Office. In their High-Resolution and Land Surface Data Assimilation project (UKMetOffice, 2010), they use data from three different numerical models: UKV, UK4 and the North Atlantic European [NAE]. All these models have 6-hourly temporal resolution, though the first two only cover the UK with 1.5 and 4km grid-scale respectively, while the NAE covers a larger area at 12km grid-scale.

The main advantage of this data is its high spatial resolution. The racing area, depending on the wind, covers more than 14km of coastline and 8km offshore (see Fig. 3). Using the UKV data of the last 5 years, focussing on July and August, we can find a very detailed climatology of local weather features such as the surface winds or sea level pressure. Similarly, using NAE data from the same period, we can include the larger scale processes in our analysis. After our statistical analysis, we should be able to give information about the common patterns, persistence and variability of weather in Weymouth Bay & Portland Harbour.

3.2 Numerical simulation of case studies

From the climatology we are able to select three case studies from the most frequent weather phenomena, such as common synoptic situations or a regular sea-breeze occurence, in the Weymouth region during the months July & August. We will further investigate these case studies, from the large-scale flow developing over several days to the small-scale effects that occur in a couple of hours, using the WRF model. Baltscheff-sky (2010) customized the WRF model to our area of interest and set up the model with three nested domains (see Fig. 4). The first domain, D1, has the most coarse resolution, covering a larger area (25×25 km with 65×65 grid-points) so that the

large-scale factors are included. The second, D2, has a resolution of 5×5 km with 81 $\times$ 81 grid-points and focusses on the English channel, to take the geographical features into account. The third domain, D3, looks at small-scale effects in at the racing area, with a fine resolution of 1×1 km with 61×61 grid-points. We plan to use this model set-up as our initial set-up for numerical simulations of our chosen case studies.
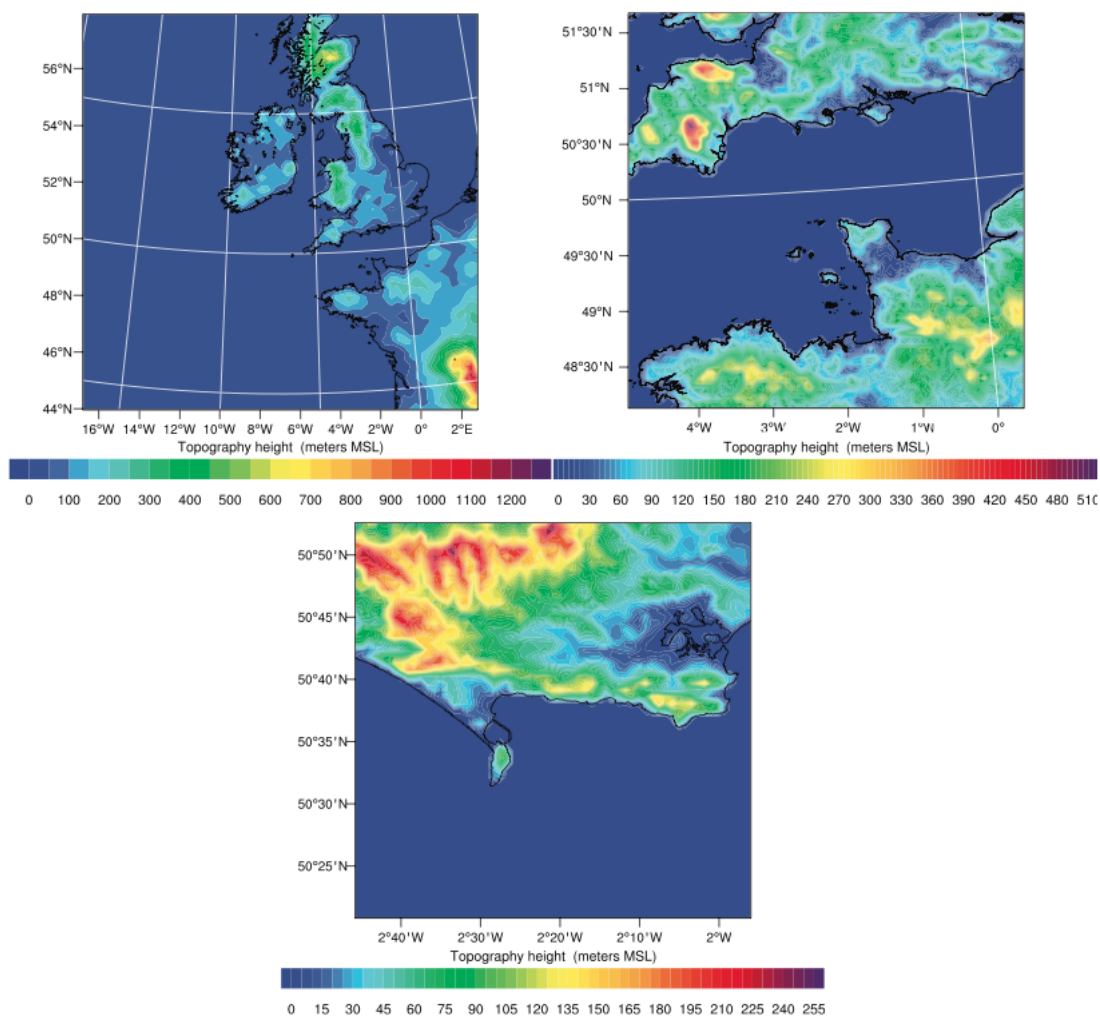

Figure 4: Three nested domains in model set-up. Top-left: D1, top-right: D2, bottom: D3. Colour scheme indicates terrain height [m].

For these numerical simulations we will use data that already fits the WRF Model input data format. It is a time-saving measure without compromising on good results, as proven by Baltscheffsky (2010). The input data will be taken from the Global Fore-

cast System final analysis dataset, provided by the National Centers for Environmental Prediction [NCEP]. The temporal resolution is 6 hours and the spatial resolution is 1.0 degree (approx. 111km). Sea surface temperature [SST] data will, initially, be taken from NCEP's global real time SST data set which also has a 6 hour temporal resolution and a spatial resolution of 0.83 degrees (approx. 92km). These simulations allow us to study small-scale costal effects, such as interaction of sea-breeze with the synoptic flow, so we can describe what triggers these frequent weather patterns and how they develop over time. For sailors it is valuable to be able to recognize weather patterns during the race. Knowing how the weather will develop gives them the chance to adjust sailing tactics.

In addition, a sensitivity analysis of schemes (e.g. planetary boundary layer scheme or turbulence scheme) used in the WRF model, will be carried out. This will be interesting for operational use of the model, during the Olympic sailing event. Apart from a weather pattern analysis done in this study, the Swiss Olympic Sailing Team has two meteorologists performing short-term weather forecasting during the sailing races. The results from our sensitivity analysis could help them with further model development.

3.3   Local knowledge

This summer, the Swiss Sailing Team will be based in Weymouth. Their coach boats, using small weather stations, will gather information on wind direction, wind speed, relative humidity, air temperature and sea temperature. These observations can be used to verify climatological findings, case study simulations and evaluation of the improved model. In addition, I will travel to Weymouth for the World Cup Championship, held in June 2011. This is a great opportunity to observe local weather conditions and meet local meteorologists and sailors. This interview will help selecting three case studies. Moreover, it will be interesting to compare their findings with our climatological and model analysis, as these experts have gained local knowledge through experience.

4 Timeline

Month (2011)	Task
June	Literary research go to UK for World Cup local knowledge interviews
July	Statistical analysis
August	Select 3 case studies Set-up WRF Model
September	Evaluation with observations Start case study I
October	Finish case study I Case study II
November	Case study III Sensitivity analysis
December	Write report

References

[1] Raymond W. Arritt. Effects of the Large-Scale Flow on Characteristic Features of the Sea Breeze. *Journal of Applied Meteorology*, 32(1):116–125, 1993.

[2] Royal Yachting Association. Notice of Race. Online, Weymouth & Portland, 2011.

[3] Magnus Baltscheffsky. Simulation and analysis of wind characteristics in the region hosting the sailing competitions of the 2012 Olympic Games. Master's thesis, Uppsala University, 2010.

[4] F.Y. Cheng and K.P. Georgakakos. Statistical analysis of observed and simulated hourly surface wind in the vicinity of the Panama Canal. *International Journal of Climatology*, 31(5):770–82, April 2011. ISSN 0899-8418.

[5] D. Houghton and F. Campbell. *Wind strategy*. Wiley Nautical, 2005.

[6] S. A. Hsu. *Coastal Meteorology*. Academic Press, 2001.

[7] J.B. Klemp, W.C. Skamarock, and J. Dudhia. Conservative Split-Explicit Time Integration Methods for the Compressible Nonhydrostatic Equations. *Monthly Weather Review*, 135:2897–2913, August 2007.

[8] X. Li. Coastal wind analysis based on active radar in Qingdao for Olympic sailing event. In *Proceedings of ISPRS Congress Beijing 2008*, pages pp. 653–658, Beijing (China), July 2008. ISPRS.

[9] MetEd. Low-level coastal jets, May 2004. URL `http://www.meted.ucar.edu/mesoprim/coastaljets/`.

[10] UK MetOffice. High-resolution and land surface data assimilation, March 2010. URL `http://www.metoffice.gov.uk/research/areas/data-assimilation-and-ensembles/high-resolution-data-assimilation`.

[11] Gary Mortimer. UAS technology helps British sailing team. *sUAS News*, December 2010.

[12] W. A. Nuss. Coastal meteorology. In James R. Holton, editor, *Encyclopedia of Atmospheric Sciences*, pages 498 – 504. Academic Press, Oxford, 2003. ISBN 978-0-12-227090-1. doi: 10.1016/B0-12-227090-8/00116-0.

[13] M.D. Powell. Wind forecasting for Yacht Racing at the 1991 Pan American Games. *B AM METEOROL SOC*, 74(1):5–16, January 1993.

[14] MD Powell and SK Rinard. Marine forecasting at the 1996 Centennial Olympic Games. *Weather and Forecasting*, 13(3, Part 2):764–782, September 1998. ISSN 0882-8156.

[15] W.C. Skamarock, J.B. Klemp, J. Dudhia, D.M. Gill, M. Duda, X.Y. Huang, W. Wang, and J.G. Powers. *A Description of the Advanced Research WRF Version 3*. NCAR Technical Note, 2008.

[16] E Spark and GJ Connor. Wind forecasting for the sailing events at the Sydney 2000 Olympic and Paralympic Games. *Weather and Forecasting*, 19(2):181–199, April 2004. ISSN 0882-8156.