Modification of the Near-Surface Temperature Field Inland from a Coastal Discontinuity

A contribution to subproject CAPMAN

S.E. Larsen, F. Dunkerley, T. Mikkelsen and A.M. Sempreviva

Riso National Laboratory, Dept. of Meteorology and Wind Energy
P.O. Box 49, DK-4000, Roskilde, Dänemark

Summary

In 2000 analysis of the JYLEX data set has been used to verify a model linking the growth of the coastal internal boundary layer (CIBL) to near-surface temperature field. This model will in turn be used as input to a simple linear model for the modification to the mean flow across the coastline.

Aim of Research

In order to predict the modification of the wind field at a coastal discontinuity a description of the CIBL is required. The CIBL height (λ) is not an easily measured parameter and, although a number of models for this have been compared with experimental data (e.g. Gryning and Batchvarova 1996, Kallstrand and Smedman 1997, Melas and Kambezidis 1992), there is no particular consensus on the most appropriate model to use. Experiments relate to different stability, roughness and terrain conditions and models require varying complexity of input.

The linear approach to wind flow modelling means that the effect on the mean wind field of changes in temperature stratification, roughness and terrain at the coastline can be considered separately. Results are generated rapidly and the aim is to run the model with minimal inputs. Both $\lambda(x)$ and $\theta(x,z)$, the potential temperature profile, are required. Hence if these parameters can be related, so that the description of CIBL can be obtained from land based temperature and wind speed measurements only, then this may provide a simple and robust method of providing information to the wind flow model.

Activity During 2000

We wish to establish a link between an assumed potential temperature profile over land downstream of the coastline (in 2 dimensions)

$$T_{land}(x,z) = T_{sea}e^{-z/\lambda_1} + \theta(x)e^{-z/\lambda(x)} \qquad (1)$$

and an assumed profile for the CIBL denoted by

$$\lambda(x) = ax^b \qquad (2)$$

where T_{sea} and $T_{land}(x,0)$ are the near surface temperatures over sea and land respectively and a and b are constants. From the literature, b is typically in the range *0.5* to *1.0*, whereas a varies more widely. Using the simplified form of the heat equation

$$U\frac{\partial\theta'}{\partial x} = -\frac{1}{\rho c_p}\frac{\partial H}{\partial z} \qquad (3)$$

where H(z) is the heat flux and U(z) is the upstream mean wind, and assuming constant entrainment $H_\lambda = -AH_0$ at $z = \lambda$, we obtain

$$\lambda \frac{\partial \theta}{\partial x} + \theta \frac{\partial \lambda}{\partial x} = \frac{g H_0 (1 + A)}{\rho c_p \theta_0 U} \tag{4}$$

Substituting for λ from (2), equation (4) becomes a 1st order ordinary differential equation in $T_{land}(x)$ which can be solved to give

$$\theta(x) = \frac{H_0 (1 + A)}{a \rho c_p U} x^{1-b} \tag{5}$$

To verify that this model is a reasonable approximation we should be able, by analysis of suitable measured values of $T_{land}(x,0) - T_{sea}$, to find constant values of *a* and *b*, which are consistent with the literature.

The JYLEX data set (Sempreviva et al., 1992) has been used for the analysis. Temperature and velocity data were collected during a two year period from measurements at four meteorological masts placed inland from the west coast of Jutland in Denmark. Previous analysis has concentrated on data averaged over season or wind sector. In this new work the individual 10 minute data records are used. The results are presented for stable or neutral conditions over the sea and unstable conditions over land for winds from 225^{o} to 304^{o}. Data from masts 1 to 3 only are used and because of the form of (5) the data set is restricted to $T_3 - T_{sea} > T_2 - T_{sea} > T_1 - T_{sea} > 0$. Heat flux data was obtained from sonic anemometer measurements. The near surface temperatures are approximated by measurements at 2m.

Table 1 contains exponents *b* and coefficients $d'(= (1 + A)/a\rho c_p)$ for nine 10^{o} wind sectors obtained by fitting a power law curve to $(T_{land}(x,0) - T_{sea})U_{sea} / H_0$ as a function of downstream distance from the coast. *Figure 1* shows the same function plotted for the 265^{o}-274^{o} sector only and the result for all sectors with summer data only is presented in Figure 2.

Table 1 Power law exponents for curve fitting

sectors	$(T_{land}(x,0) - T_{sea})U_{sea} / H_0$		
	b	d´	No of points
225-234	0.72	0.017	135
235-244	0.74	0.014	130
245-254	0.74	0.014	152
255-264	0.71	0.008	74
265-274	0.71	0.009	86
275-284	0.67	0.010	107
285-294	0.65	0.008	207
295-304	0.64	0.007	178

We can note from the results that, despite the large spread in the experimental data, the power law exponents (*b*) are consistent across changes in wind sector and season and in reasonable agreement with the literature. Differences between the sectors can be explained by the changes in fetch length from the coast to the mast 1 which affects the calculation of T_{sea} and U_{sea}. The coefficients (*d'*) for the different sectors also show good agreement. We might expect more variability in this parameter because of the relatively wide range of fluctuations in the heatflux time series calculated from the sonic data. In fact $d' = 0.01$ corresponds to $a = 0.1$ which again is reasonably consistent with the literature. (e.g. Bergstrom et al., 1988).

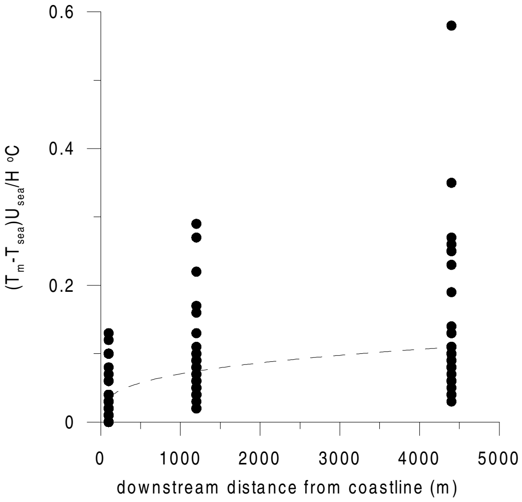

Figure 1: $(T_{land}(x,0) - T_{sea})U_{sea} / H_0$ as a function of downstream distance (x) for winds from 265° to 274°. (dashed line represents best power law fit to data.)

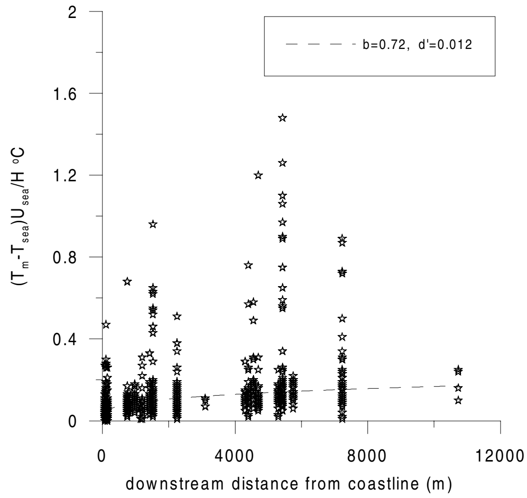

Figure 2: $(T_{land}(x,0) - T_{sea})U_{sea} / H_0$ as a function of downstream distance (x) for winds from 225° to 304° - summer data only. (dashed line represents best power law fit to data.) 645 points used.

The next aim is to expand the analysis of the JYLEX data set to include other combinations of stability conditions. The application of the same process to other appropriate data sets is also being considered.

References

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