LABORATORY SIMULATION OF TOPOGRAPHIC EFFECTS ON ATMOSPHERIC FLOWS IN STABLE CONDITIONS

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INTRODUCTION

Air flow past topography causes a number of significant dynamical effects in a stably stratified atmosphere. These can have a controlling influence on the wind field in light wind, high pollution situations. Since the shape and form of the Earth’s terrain is generally quite complex, determining what these effects are in a given region is a non-trivial task. Laboratory modelling provides a reasonably quick and relatively cheap method for investigating stratified airflow around mesoscale topography, and quantitative results may be obtained from suitably designed experiments. These are normally done with topographic models towed through stratified salt water; attempts to model stably stratified flows with topography in wind tunnels have not been very successful so far.

BASIS FOR MODELLING

The principal requirement for modelling is to make the important dynamical balances in the model as close as possible to those in the atmosphere. Complete dynamical similarity is usually impossible, and one must compromise and identify the essential parameters. Much has been learnt in recent years about stratified flow past simple topographic shapes (e.g., Snyder et al., 1985, Baines, 1987) and this information is useful in modelling...
more complex terrain. We consider a region of complex terrain such as shown in Figure 1 which defines notation, with stratification as shown in the inset. In fluid of total depth \( D \), with constant buoyancy (Brunt-Vaisala) frequency \( N \) (where \( N^2 = -g/\rho \frac{d\rho}{dz} \)) above a stable interface

![Figure 1: Schematic definition sketch for flow with mean speed \( U \) past complex terrain. The density profile is shown in the inset. A given region of complex terrain may have several values of \( a, b \) and \( h \).](image)

at height \( d \), the relevant dimensionless parameters are

\[
\frac{Nh}{U}, \frac{h}{a}, \frac{a}{b}, K = \frac{ND}{\pi U}, \frac{Re}{2U/\nu}, \frac{d}{h}, \text{and } g\Delta \rho / \rho N^2 d,
\]

where \( \rho \) is the fluid density and \( \nu \) is the kinematic viscosity. The Earth's rotation is assumed to be unimportant for the small space and time scales of interest here. Ideally, the values of these parameters should be the same in the laboratory analogue as in the atmosphere. For the Reynolds number, \( Re \), we must use "Reynolds number, \( Re \)"

### Table I

**Requirements for Laboratory Modelling of Stratified Flow Over Complex Terrain**

<table>
<thead>
<tr>
<th>( Nh/U )</th>
<th>Flow Regime</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Lee waves</td>
<td>ND/( U^2 ) ( N^2/U^2 ) &gt; 1; ( Na/\rho U ) same as for atmosphere;</td>
</tr>
<tr>
<td>0.5</td>
<td></td>
<td>( h/\rho U ) same as for atmosphere for quantitative results</td>
</tr>
<tr>
<td>1.0</td>
<td></td>
<td>( h/\rho U ) same as for atmosphere for quantitative results</td>
</tr>
<tr>
<td>2.0</td>
<td>Columnar (blocking) disturbances</td>
<td>( Ub/\nu \gg 1 )</td>
</tr>
<tr>
<td>4.0</td>
<td></td>
<td>( h/\rho U ) same as for atmosphere for quantitative results</td>
</tr>
</tbody>
</table>

\( a/b, d/h \) and \( g^2/N^2 d \) should both have equal values in the laboratory and atmosphere respectively. Other criteria depend on \( Nh/U \), as follows:

If \( d = 0 \) we have

\( \frac{Nh}{U} = \frac{D}{U} \) and \( \frac{h}{\rho U} = v \) should both have equal values in the laboratory and atmosphere respectively.

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INTRODUCTION

The Queensland Electricity Commission operates a 1650 MW coal-fired power station at Gladstone, an important industrial centre on the Queensland coast. The Commission maintained a continuous air monitoring network in the Gladstone region from August 1982 until March 1986.

The major objective of the network was to determine the impact of the power station on air quality in the Gladstone region, including the identification of the causes (e.g. power station operations or meteorological conditions) of any significant effects on air quality. A subordinate objective during the final year of the network's operation was to gather sufficient data on meteorological conditions, ground-level concentrations (glec's) and emissions for future power station design (e.g. the setting of stack heights) as well as a determination of the air quality effects at sites not directly monitored in the Gladstone region.

THE NETWORK

The power station's effects on air quality have been clearly identified by the continuous monitoring. To be successful, dispersion models need to be able to reproduce these effects. This paper describes some measured characteristics of plume effects in the near sub-tropical coastal region.

A total of eight sites were monitored for various periods. Sulfur dioxide (SO₂), oxides of nitrogen, particulates and ozone (O₃) were recorded. After determining that the higher SO₂ glec's occurred during NE sea-breeze conditions, the network was realigned in September 1985 to provide four monitoring site in line to the SW of the station to determine the magnitude and location of the highest glec's.

The network of air quality monitors and instrumented 10m meteorological towers was supplemented by an upper-level meteorological study and a continuous recording of stack emissions of (SO₂) and nitric oxide (NO) during its final year of monitoring.

Additional studies (including also an instrumented aircraft and tracer gas releases) measured dispersion parameters necessary for the future Stanwell Power Station Stack Height determination and also the rate of oxidation of nitric oxide into the more toxic nitrogen dioxide (NO₂).