Contents of this CD-ROM

This CD-ROM is an attachment to the book *Marine Turbulence: Theories, Observations, and Models* edited by Helmut Z. Baumert, Jürgen Sündermann, John Simpson, and six guest editors, published by Cambridge University Press. This CD-ROM was edited by Patrick Luyten.

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I. Introduction

An integral part of theoretical, observational, and modeling approaches to marine turbulence is constituted by data sets that corroborate the research findings. We have gathered data sets obtained during measurement campaigns for a diverse set of ocean environments and extractions of data resulting from numerical turbulence model experiments. Not all of these data sets were obtained directly by the scientists belonging to the CARTUM Partnership, and we acknowledge in each case the originating principal investigator who released the data included on the CD-ROM.

The second type of information contained in the CD-ROM is codes of turbulence models that are freely available to the scientific community. The first one was initially developed by a group of researchers working at the Joint Research Center in Ispra, Italy. The **GOTM (General Ocean Turbulence Model)** development team has been designing and writing modular turbulence codes representing the principal turbulence-parameterization approaches (k - ε and k - l) since the mid 1990s, which they have been making freely available under the GNU Public License Agreement. Initially GOTM was focusing on a one-dimensional turbulence model, which is now being integrated into three-dimensional ocean models. The second is **PROWQM (PROVESS Water Column Model)**, developed at MUMM (Management Unit of the Mathematical Models, Brussels, Belgium and Napier University, Edinburgh, UK) during the 1998 - 2001 European PROVESS project. Beside an extensive series of turbulence closure schemes, interfaces that allow the integration of new modules for biology and sediments are provided.

II. Data sets on this CD-ROM

The CD-ROM contains a total of ten different data sets located in the sub-directories of the **\data** directory. The meaning of each file can be inferred from its name, which is composed as follows:

```
dataset_name + contents + '_' + format + '.' + file_type
```

- `dataset_name` is the name of the data set as given by the name of the sub-directory.
- `contents` refers to the specific contents of the file.
- `format` specifies one of the five data formats described below.
- `file_type` is either `txt` for an internal documentation file with text only or `dat` for a data file containing only numerical values.

II.1 Formats

- `tser`: time series of depth-independent parameters.
- `prof`: vertical profiles at a fixed (or unspecified) time. The first column represents the water depths.
- `tzcl`: time series of vertical profiles in column format. The first column represents the water depth (or height above the sea bed). Depth levels may be different at different times.
- `tzrw`: time series of vertical profiles in row format. Depth levels are constant in time and supplied as part of the file headings.
- `tdep`: the same meaning as `tzrw` but presented in `tser` format.

An example generic FORTRAN 90 file (`fcartum.f`) is provided, explaining how to read and interpret the numerical fields in the data files.

II.2 Documentation

The internal documentation in the `txt` files is supplied in a standard format and contains the following information:

- titles for graphical display
- source or principal investigator of the data set
- geographical location: either fixed in time, or else specified in the data file
- name of the corresponding data file
- start and end date/time
- time step (may be irregular)
- number of time series
- presence of flagged data
- depth interval, minimum and maximum depth of data collection, number of depth levels (may be irregular)
- number of data fields
- field descriptors: FORTRAN name, type, and format; short description; unit; method.

II.3 Description of the data files

II.3.1 Directory \Banda

Long-term observations at mooring station Banda (34°58′50′′N, 139°46′23′′E). Data are provided at hourly intervals between February 18, 1994 and January 31, 1999.

- `Bandacur_tser.dat`: horizontal current magnitude and direction at depths 5 and 25 m.
- `Bandamet_tser.dat`: surface forcing data (mean and maximum wind speed, mean wind direction, incoming shortwave radiation, net surface heat flux, rainfall, air and sea-surface temperature, relative humidity, atmospheric pressure, and sea-surface salinity).
- `Bandatemp_tdep.dat`: temperature at 3-m intervals and ten depth levels.

II.3.2 Directory \Flex76

Mooring data at the FLEX station within the North Sea (58°55′N, 32′E) in 1976.

- `Flex76_tser.dat`: surface forcing data at hourly intervals between April 6 and June 8, 1976 (wind components, atmospheric pressure, air and sea-surface temperature, wet bulb temperature, short- and long-wave radiation).
- `Flex76_tzrw.dat`: temperature at 2.5 m, 6-hourly intervals and 56 depth levels between March 24 and June 12, 1976.

II.3.3 Directory \Globec

Microstructure, ADCP, and CTD data from the Globec cruises in October 1998. Meteorological data from Shearwater airport.

- `Globecadcp_tzcl.dat`: ADCP data (currents and error velocity) and temperature at 4-m intervals and 19 depth levels for October 8 and 9 (43°33′N–43°52′N, 61°10′–61°57′W).
- `Globecdielctd_tzcl.dat`: CTD data (temperature, salinity, density anomaly) at 1 m intervals and 48 depth levels for October 8 and 9 (43°43′–43°51′N, 61°13′–61°21′W).
- `Globecepsavr_tzcl.dat`: time-averaged microstructure and CTD data from Epsonde probe (temperature, salinity, density anomaly, buoyancy frequency, dissipation of turbulence energy and temperature variance, vertical diffusivity for density and temperature) at 2-m intervals and 40 depth levels between October 1 and 16 (43°37′–44°1′N, 61°9′–61°47′W).
- `Globecepsctd_tzcl.dat`: unaveraged CTD data from Epsonde probe (temperature, salinity, density anomaly, buoyancy frequency) between September 28 and October 16 (43°37′N–44°2′N, 61°9′–61°48′W).

- `Globecepsmax_tzcl.dat`: 95% upper confidence limit for time-averaged microstructure and CTD data from Epsonde probe (temperature, salinity, density anomaly, buoyancy frequency, dissipation of turbulence energy, and temperature variance, vertical diffusivity for density and temperature) at 2-m intervals and 40 depth levels between October 1 and 16 (43°37′–44°1′N, 61°9′–61°47′W).
- `Globecepsmic_tzcl.dat`: unaveraged microstructure data from Epsonde probe (dissipation of turbulence energy and temperature variance from two sensors, vertical diffusivity for density and temperature, vertical heat flux, Cox number, and mixing efficiency) between September 28 and October 16 (43°37′N–44°2′N, 61°9′–61°48′W).
- `Globecepsmin_tzcl.dat`: 95% lower confidence limit for time-averaged microstructure and CTD data from Epsonde probe (temperature, salinity, density anomaly, buoyancy frequency, dissipation of turbulence energy and temperature variance, and vertical diffusivity for density and temperature) at 2-m intervals and 40 depth levels between October 1 and 16 (43°37′–44°1′N, 61°9′–61°47′W).
- `Globecmet_tser.dat`: surface forcing data (44°38′N, 63°30′W) at hourly intervals between October 1 and November 30 (wind speed and direction, dry- and wet-bulb temperature, dew-point temperature, relative humidity, atmospheric pressure, and cloud coverage).

II.3.4 Directory \IrishSea

Microstructure and forcing data at two Irish Sea mooring stations in 1993.

II.3.4.1 Sub-directory \M1

Mooring data at station M1 (53°51′12′′N, 4°25′36′′W) in March 1993.

- `IrishSeaM1ctd_prof.dat`: CTD temperature and salinity at 1-m intervals and 39 depth levels.
- `IrishSeaM1dis_tzrw.dat`: dissipation of turbulence energy from FLY probe at 15-cm intervals and 333 depth levels for March 25 and 26.
- `IrishSeaM1met_tser.dat`: surface forcing data at hourly intervals between March 20 and April 1 (wind speed and direction, dew point temperature and short wave radiation).
- `IrishSeaM1tsc_tser.dat`: horizontal current components, temperature, and salinity at 1 min intervals and at 41 and 5 m above the seabed for March 25 and 26.

II.3.4.2 Sub-directory \S1

Mooring data at station S1 (56°51´18´´N, 5°26´54´´W) in July 1993.

- `IrishSeaS1ctd_prof.dat`: CTD temperature, salinity and density anomaly at about 2-m intervals and 44 depth levels.
- `IrishSeaS1dis_tzrw.dat`: dissipation of turbulence energy from FLY probe at 15-cm intervals and 533 depth levels for July 6 and 7.
- `IrishSeaS1met_tser.dat`: surface forcing data at hourly intervals between June 28 and July 11 (wind speed and direction, dew-point temperature, and short-wave radiation).
- `IrishSeaS1temp_tzrw.dat`: temperature at 20-cm intervals and 465 depth levels for July 6 and 7.
- `IrishSeaS1tsc_tser.dat`: horizontal current components, temperature, and salinity at 1-min intervals and at 81 and 9 m above the sea bed for July 6 and 7.

II.3.5 Directory \LES

Numerical data from five Large-Eddy Simulation (LES) experiments for free and rotating turbulent convection.

II.3.5.1 Sub-directory FC

FC-experiment:

- `LESFC2cor_prof.dat`: second-moment correlations normalized with Deardorff scales (u^2, w^2, θ^2 and p^2correlations, turbulence energy).
- `LESFC3cor_prof.dat`: third-moment correlations normalized with Deardorff scales (w^3, wu^2, $w^2\theta$, $w\theta^2$ and wp-correlations).
- `LESmean_prof.dat`: mean temperature minus its minimum value (normalized using the depth of the convective boundary layer and Deardorff scales).
- `LESFCskew_prof.dat`: skewness parameters for vertical velocity and temperature.
- `LEStkebd_prof.dat`: balance terms in the turbulence energy equation normalized using Deardorff scales (buoyancy, turbulent and pressure transport, dissipation terms).
- `LESFCttbd_prof.dat`: balance terms in temperature variance (θ^2) equation normalized using Deardorff scales (gradient, transport and dissipation terms).
- `LESFCwtbd_prof.dat`: balance terms in the heat flux ($w\theta$) equation normalized using Deardorff scales (gradient, transport, buoyancy, and resolved and SGS pressure terms).

II.3.5.2 Sub-directories \D0, \D2, \R2, \R3

D0, D2, R2, and R3 experiments. Files have the same meaning as for the FC experiment with `FC` replaced by, respectively, `D0`, `D2`, `R2, and R3`.

II.3.6 Directory \LagoMaggiore

Microstructure measurements in the Lago Maggiore (45°49′14′′N, 8°36′23′′E) of convective cooling for December 18 to 21, 1995.

- `LagoMaggiore_tser.dat`: surface forcing data at 30 min intervals (atmospheric pressure, air and sea-surface temperature, cloud coverage, short-wave and total surface heat flux, relative humidity, North−South component of wind and surface stress).
- `LagoMaggiore_tzcl.dat`: potential temperature and microstructure data (dissipation of turbulence energy and of temperature variance, and temperature variance as such) at 15-cm, 30-min intervals and 203 depth levels.

II.3.7 Directory \November

Long-term observations at Ocean Weather Station November (30°N, 140°W).

- `November_tser.dat`: surface forcing data at 3-h intervals (wind speed and direction, air and sea-surface temperature, wet-bulb and dew-point temperature, cloud coverage and atmospheric pressure) between November 27, 1959 and April 30, 1974.
- `November_tzrw.dat`: temperature at 5 m intervals and 60 depth levels between February 9, 1960 and December 31, 1970.

II.3.8 Directory \Papa

Long-term observations at Ocean Weather Station Papa (50°N, 145°W).

- `Papa_tser.dat`: surface forcing data at 3-h intervals (wind speed and direction, air and sea-surface temperature, wet-bulb and dew-point temperature, cloud coverage, and atmospheric pressure) between September 14, 1959 and June 22, 1981.
- `Papa_tzrw.dat`: temperature at 5-m intervals and 60 depth levels between January 1, 1960 and December 30, 1968.

II.3.9 Directory \Provess

Cruise and mooring CTD, ADCP, temperature, salinity, and microstructure data at two sites in the North Sea.

II.3.9.1 Sub-directory \nns

Data at (or near) the northern Provess site (59°20′N, 1°E) during the autumn of 1998.

- `ProvessnnsDANctd_tzcl.dat`: Dana cruise CTD data (temperature, salinity, potential temperature, and density) at 0.5-m intervals and 211 depth levels between October 16 and October 25, 1998.
- `ProvessnnsFLY_tzcl.dat`: microstructure and CTD data from FLY probe (temperature, salinity, density anomaly, and dissipation of turbulence energy from two sensors) between October 21 and October 27, 1998.
- `ProvessnnsMSTbvf_tzcl.dat`: buoyancy frequency from MST probe at 231 depth levels between October 16 and October 24, 1998.
- `ProvessnnsMSTchi_tzcl.dat`: dissipation of temperature variance from MST probe at 229 depth levels between October 16 and October 24, 1998.
- `ProvessnnsMSTcox_tzcl.dat`: Cox number from MST probe at 229 depth levels between October 16 and October 24, 1998.
- `ProvessnnsMSTctd_tzcl.dat`: CTD data (temperature, salinity, density anomaly and potential density) from MST probe at 231 depth levels between October 16 and October 24, 1998.
- `ProvessnnsMSTedd_tzcl.dat`: vertical diffusion coefficient for density from MST probe at 229 depth levels between October 16 and October 24, 1998.
- `ProvessnnsMSTeps_tzcl.dat`: dissipation of turbulence energy from MST probe at 229 depth levels between October 16 and October 24, 1998.
- `ProvessnnsMSTtho_tzcl.dat`: Thorpe scale, mean, and maximum Thorpe displacement from MST probe at 231 depth levels between October 16 and October 24, 1998.
- `ProvessnnsPELctd_tzcl.dat`: Pelagia cruise CTD data (temperature, salinity, potential temperature and density) at 0.5-m intervals and 248 depth levels between October 21 and October 28, 1998.
- `Provessnnsadcp_tser.dat`: ADCP data (currents and error velocity) at 4-m, 10-min intervals and 22 depth levels between October 16 and October 28, 1998 (59°19′42′′N, 1°12′′E).
- `Provessnnsmet_tser.dat`: surface forcing data at hourly intervals (59°33′N, 1°32′E) from the UK Meteorological Office between October 16 and October 29, 1998 (atmospheric pressure, wind speed and direction, dry bulb temperature, significant wave height, and zero-crossing period).
- `Provessnnsthm_tdep.dat`: temperature data from a moored thermistor chain (59°20′N, 1°5′E) at 5 m, 5 min intervals and 11 depth levels between October 16 and October 29, 1998.

II.3.9.2 Sub-directory \sns

Data at (or near) the southern Provess site (52°18´N, 4°18´E) during the spring of 1999.

- `ProvesssnsBELctd_tzcl.dat`: Belgica cruise CTD data (temperature, salinity, potential temperature and density anomaly) at 0.5-m intervals and 36 depth levels between May 17 and May 20, 1999.
- `ProvesssnsFLYmcs_tzcl.dat`: microstructure and CTD data from FLY probe (temperature, salinity, density anomaly and dissipation of turbulence energy from two sensors) between April 2 and April 7, 1999 .
- `ProvesssnsHYDmcs_tzcl.dat`: CTD and microstructure data from MST probe (temperature, salinity, density anomaly, buoyancy frequency, Thorpe scale, temperature variance and gradient) between May 17 and May 20, 1999.
- `ProvesssnsMITctd_tzcl.dat`: Mitra cruise CTD data (temperature, salinity, potential temperature and density anomaly) at 0.5-m intervals and 50 depth levels between April 19 and April 29, 1999.
- `ProvesssnsNIOZadcp_tzcl.dat`: ADCP data (currents and error velocity) at 0.5-m, 20-s intervals and 27 depth levels (52°18´6´´N, 4°18´E) between April 1 and April 8, 1999.
- `ProvesssnsPELctd_tzcl.dat`: Pelagia cruise CTD data (temperature, salinity, potential temperature and density anomaly) at 0.5-m intervals and 54 depth levels between March 29 and April 8, 1999.
- `ProvesssnsPOLadcp_tzcl.dat`: ADCP data (currents and error velocity) at 0.5-m, 5-min intervals and 35 depth levels (52°19´12´´N, 4°11´42´´E) between March 30 and May 18, 1999.
- `ProvesssnsPOLsalin_tdep.dat`: salinity data from moored TCP chain logger (52°18´12´´N, 4°18´18´´E) at 2.5 m, 5-min intervals and five depth levels between March 30 and May 20, 1999.
- `ProvesssnsPOLtemp_tdep.dat`: temperature data from moored TCP chain logger (52°18´12´´N, 4°18´18´´E) at 2.5 m, 5-min intervals and five depth levels between March 30 and May 20, 1999.
- `ProvesssnsSAIbvf_tzcl.dat`: buoyancy frequency from MST probe (52°16´26´´N, 4°17´45´´E) at 90 depth levels between April 21 and April 29, 1999.
- `ProvesssnsSAIchi_tzcl.dat`: dissipation of temperature variance from MST probe (52°16´26´´N, 4°17´45´´E) at 92 depth levels between April 28 and April 29, 1999.
- `ProvesssnsSAIcox_tzcl.dat`: Cox number from MST probe (52°16´26´´N, 4°17´45´´E) at 92 depth levels between April 28 and April 29, 1999.
- `ProvesssnsSAIctd_tzcl.dat`: CTD data (temperature, salinity, density and potential density anomaly) from MST probe (52°16´26´´N, 4°17´45´´E) at 90 depth levels between April 21 and April 29, 1999.
- `ProvesssnsSAIedd_tzcl.dat`: vertical diffusivity for temperature from MST probe (52°16´26´´N, 4°17´45´´E) at 92 depth levels between April 21 and April 29, 1999.
- `ProvesssnsSAIeps_tzcl.dat`: dissipation of turbulence energy from MST probe (52°16´26´´N, 4°17´45´´E) at 92 depth levels between April 21 and April 29, 1999.
- `ProvesssnsSAItho_tzcl.dat`: Thorpe scale, and mean and maximum Thorpe displacement from MST probe (52°16´26´´N, 4°17´45´´E) at nine depth levels between April 21 and April 29, 1999.

- `Provesssnsmet_tser.dat`: surface forcing data at hourly intervals (52°16′24′′N, 4°17′48′′E) from the Dutch Meteorological Office between March 1 and May 31, 1999 (wind speed and direction, sea-surface temperature, significant wave height, and zero crossing period).

II.3.10 Directory \TropicHeat84

Cruise data of equatorial turbulence at 140°W during 1984.

- `TropicHeat84_tser.dat`: surface forcing data at 2-hourly intervals between November 15 and December 3, 1984 (sea-surface, dry-bulb and wet-bulb temperature, wind speed, surface stress, short- and long-wave radiation, latent and sensible heat flux, and surface buoyancy flux from temperature and salinity).
- `TropicHeat84_tzcl.dat`: CTD and microstructure data (temperature, salinity, buoyancy frequency, zonal, meridional and total shear, Richardson number, dissipation of turbulence energy and temperature variance) at 6.36 m, hourly intervals and 22 depth levels between November 25 and 30, 1984.

II.4 Data flags

The data are associated with one of the following qualifying data flags:

- `blank`: valid data
- `M`: missing data (data value set to zero)
- `L`: invalid data (data value set to zero)
- `S`: suspect data (data value set to zero)
- `I`: interpolated value

III Models on this CD-ROM

The two different model codes stored on this CD-ROM are located in sub-directories of the **\data** directory. To retrieve the code and test cases, use (on any UNIX machine)

```
tar –xvf gotm.tar
```

or

```
tar –xvf prowqm.tar
```

III.1 Directory \gotm

Most of the GOTM (Global Ocean Turbulence Model; Burchard *et al*., 1999) Home Page has been stored on the CD-ROM. These Web Pages represent a snapshot of the GOTM Project from February, 2002 and can be viewed by loading the file `index.html` , located in the **\gotm** sub-directory , into the internet browser.

The GOTM Web pages on this CD-ROM allow the following options.

- Understanding the basic ideas of GOTM.
- Downloading various (FORTRAN 77 and FORTRAN 90) versions of the GOTM source code.
- Learning how to install and compile the GOTM source code.
- Downloading several idealized and realistic GOTM scenarios.
- Learning how to carry out GOTM simulations of these scenarios.
- Studying the FAQ (Frequently Asked Questions) page.
- Knowing the persons and projects behind GOTM.

The real online GOTM Web Pages allow some additional options that could not be recovered from the CD-ROM and for which all external links had to be channeled to a "Dead Link" page. For further scientific information on GOTM, the reader is referred to the original GOTM report (Burchard *et al*., 1999) or to some sections of the attached book *Marine Turbulence: Theories, Observations, and Models*.

Reference

Burchard, H., Bolding, K., and Villareal, M.R. (1999). *GOTM – A General Ocean Turbulence Model. Theory, Applications and Test Cases*. European Commission Rep. EUR 18745 EN, 103 pp.

III.2 Sub-directory \prowqm

PROWQM (Provess Water Column Model) is a one-dimensional integrated water column model, which constructed and validated within the European PROVESS (MAS3-CT97-0159) project. Its main objective is to provide a common framework and userplatform for the validation and testing of new or existing schemes for turbulence and of modules for biology and sediments prior to their implementation into three-dimensional numerical ocean models. Easily accessible interfaces are provided for (future) integration of new or alternative modules for biology and/or sediment resuspension without large computational and programming overheads. This allows one to use PROWQM as a user-friendly platform for the testing and intercomparison of biological and sedimentological models and to assess their sensitivity to the formulation of vertical exchange processes (turbulence, resuspension).

The code is supplied with 14 different test cases and has, in particular, been applied to the Papa, November, Flex, Irish Sea, Lago Maggiore and Provess data sets, included on the CD-ROM. A scientific discussion is given on the attached book *Marine Turbulence: Theories, Observations, and Models*.

A more detailed documentation of PROWQM can be found in the associated PostScript document `prowm.ps`.

IV Color figures on this CD-ROM

To keep the price of the book "Marine Turbulence .." within limits, all figures are presented in black and white in the book but, where some figures need significant use of color, these are included on this CD-ROM in the directory **\FIGURES**. This directory contains all color figures of the book as PDF files. The file names correspond directly to the figure numbers appearing in the text of the printed book. Here is an example:

- In the printed book, the caption of Figure 12.4 includes a notice that *this figure is available as a color PDF on the attached CD-ROM.*
- This tells you that you will find a color version of Figure 12.4 on this CD-ROM in the directory **\FIGURES**.
- Go to this directory and double click on **FIG12-4.PDF** to open it.

The general name convention for figures files on this CD-ROM is fully analogous to the figure-name convention in the book, eg **FIGX-Y.PDF** means Figure number **Y** in Chapter number **X** of the book.

Technical requirements

Before you can view the a.m. files, it is necessary to install *Adobe Acrobat Reader 4.0* (or a higher version of this program) on your computer. This useful software may be downloaded from the following internet site:

http://www.adobe.com/products/acrobat/readstep2.html

Specific requirements other than the necessity to have a CD drive, a mouse, a color screen and MS Windows version 95 or better on your PC are not known to the editors and authors of the attached book.

Some of the files in the subdirectories MODELS / GOTM / … can only be accessed using special software. Information about the tools needed may be found on the following internet site:

http://www.gotm.net