To develop quantitative means (hydrodynamic diagrams) to determine the hydrodynamic state of microstructure patches in stratified and rotating flows such as the ocean; that is, whether the patches represent active turbulence, active-fossil turbulence, or completely fossil turbulence. A precise definition of turbulence has been proposed that shows the direction of the turbulence cascade usually assumed is incorrect. The Reynolds rules of averaging postulates of 1894 used in dissipation flux balances such as the Osborn and Cox (1972) equation $K=DC$ are re-examined by a control volume averaging technique in Gibson (JGR Nov. 1991), that reveals the need for averaging over very large data sets, with length scales larger than the largest turbulence scales in either the horizontal or vertical.
Analysis of Soviet Microstructure Data

Research Goals:

The ultimate goal is to acquire a better understanding of stratified and rotating turbulence and mixing processes so that measurements of ocean microstructure, mesostructure and other variables can be used to make reliable inferences about vertical fluxes of heat, mass, and momentum.

Objectives:

The near term objectives are to continue to analyze, interpret, and publish sensor characteristics and measurement results from towed body and dropsonde microstructure and fine structure data collected during the 51st Cruise of the R/V AKADEMIK KURCHATOV, a Research Vessel of the Shirshov Institute of Oceanology, Academy of Sciences of the (former) USSR (IOAN). In addition, other data sets collected in FSU cruises and expeditions will be identified, evaluated, and processed, in collaboration with various scientists of the FSU. Temperature dissipation rates in the California coastal upwelling region were found to be precisely lognormal averaged over a wide range of averaging scales, with an intermittency constant close to values reported in the atmosphere and interstellar medium, as reported in Gibson (Proc. Roy. Soc. 1991). Similar statistical tests have been made by Lozovatsky and Erofeev in other regions from the towed body GRIF, and give rather different results when the range of the mixing cascade is attenuated. The role of island wakes in vertical mass, heat, and momentum transport in equatorial regions can be evaluated from the dropsonde and towed body data collected during AK51. Statistical properties of mixing and turbulent activity coefficients will also be studied, and compared to results in Gibson, Nabatov and Ozmidov (1993). Unique microstructure sensor systems developed in the FSU need to be identified, tested, and intercompared with each other and Western sensors. For example, Prandke and his colleagues at Rostock-Warnemunde have developed a shear probe with
much better strength, sensitivity, and spatial resolution than those used in the West with which he
and Stips have identified Baltic microstructure as mostly fossilized remnants of previous
turbulence activity. The probe is routinely stabbed into the bottom without harm.

Approach:

The approach has been to continue the good relationship with Soviet ocean turbulence experts
that has been on going since 1972. The first microstructure intercomparison cruise was on the
11th Cruise of the DMITRI MENDELEEVEV in 1974 with Schedvin and Deaton, and Ozmidov,
Paka, Lozovatsky, Nabatov and others of IOAN Moscow and Kaliningrad, in which Schedvin
(1977) measurements gave the first decisive evidence of fossil temperature turbulence, forming
the basis of the Gibson (1980) fossil turbulence model. Such scalar remnants are much more
persistent than the fleeting active turbulence events that produce them, and preserve information
that can be used with proper modeling to make more reliable estimates of average dissipation
rates and vertical fluxes. Estimates that ignore or dispute the turbulence fossilization phenomena
are subject to truly egregious undersampling errors, typically underestimating true average
dissipation and flux values by factors of one to five orders of magnitude. Most Western
microstructure studies have taken this latter approach, and have attempted to solve the
intermittency problem by collecting enormous numbers of dropsonde samples. Unfortunately,
most of these are from the same region, and lack independence. Fortunately, excellent evidence
of the turbulence fossilization process has accumulated, and evidence of a new crucially
important phenomena, termed "fossil turbulence waves" by Gibson (JGR, Nov. 1991), have
emerged.

Tasks Completed:

Publication of ideas about fossil turbulence in Western oceanographic journals has been a
difficult task. One reason has been that active turbulence patches are so rare in the ocean that
many published data sets contain no examples with $AT > 1$, where completely active turbulence
is identified as a patch with viscous dissipation epsilon larger than epsilon sub 0 equal either
$13DCN^2$ or $3L^2N^3$ from Gibson (1980) at the buoyancy-inertial transition (critical
Froude number) where fossilization begins, where $L$ is the maximum vertical density overturn
scale, $D$ is the molecular diffusivity of the scalar field, $C$ is the Cox number, and $N$ is
the ambient Vaisala frequency of the patch, and $AT = (\epsilon/\epsilon_0)^{1/2}$ is the turbulence activity
parameter of Gibson (1980). How is it possible to measure thousands of microstructure patches
and rarely see one with $AT > 1$? The answer is that it is not possible, and numerous patches in
the ocean have been detected with $AT > 1$. To find many patches with $AT > 1$, measurements
near an ocean turbulence source are needed, and these were supplied by the dropsonde BAKLAN
measurements of Nabatov and Ozmidov near Ampere Seamount. The results are shown in the
attached hydrodynamic phase diagram. A patch in the Arcticin the completely active state has
finally been reported, by Wijesekera and Dillon (1997), the first ever except for the Ampere
Seamount results of Gibson, Ozmidov and Nabatov(1993).
Scientific Results:

Data analysis from AK51 continues, with results given in a number of publications and works in progress listed previously. An overall view of currents, shear, and stratifications for the dateline Pacific equatorial undercurrent, with typical microstructure patterns, are reported in Lilover et al. (1993). AT and temperature dissipation rate values in the surface (Western) and subsurface (Eastern) wakes of Baker and Howland islands have been recently computed by Lozovatsky and Erofeev, and are being evaluated. Preliminary sensor tests by Baker will be published in Gibson, Nabatov, and Ozmidov (DAO 1993).

Accomplishments:

Probably the most important accomplishment of this work has been to develop quantitative means (hydrodynamic phase diagrams) to determine the hydrodynamic state of microstructure patches in stratified and rotating flows such as the ocean; that is, whether the patches represent active turbulence, active-fossil turbulence, or completely fossil turbulence. A precise definition of turbulence has been proposed that shows the direction of the turbulence cascade usually assumed is incorrect. The Reynolds rules of averaging postulates of 1894 used in dissipation flux balances such as the Osborn and Cox (1972) equation $K=DC$ are re-examined by a control volume averaging technique in Gibson (JGR Nov. 1991), that reveals the need for averaging over very large data sets, with length scales larger than the largest turbulence scales in either the horizontal or vertical.

ONR-Sponsored Publications


Statistics

9 Papers published, refereed journals
4 Papers submitted, refereed journals
0 Books or chapters published, refereed publication
0 Books or chapters submitted, refereed publication
1 Invited presentations
4 Contributed presentations
0 Technical reports and papers, non-refereed journals
0 Undergraduate students supported
0 Graduate students supported
0 Post-docs supported
0 Other professional personnel supported

EEO/Minority Support
0 Female grad students
0 Minority grad students
0 Asian grad students
0 Female post-docs
0 Minority post-docs
0 Asian post-docs

Patents and awards:

Influences:

The most influential books were Landau and Lifshits; Fluid Mechanics, and Phillips; The Dynamics of the Upper Ocean.


abyssal dropsondes
laboratory jets and wakes
dominant abyssal events
seamount wakes
seasonal thermocline

active turbulence
abyssal turbulence begins
wakes

active-fossil turbulence

mixing efficiency

Wijesekera & Dillon (1997)
fossilization begins

equatorial undercurrent shear layer
dominant equatorial events

T_A,F = 3 N^1 \log \frac{\varepsilon_F}{\varepsilon_F}

\frac{Rc}{Re_T} = \left[ \frac{\varepsilon}{\varepsilon_F} \right]