Fossil turbulence and fossil turbulence waves permit remote sensing of submerged submarines

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Abstract. Turbulence defined by dominant inertial vortex forces always cascades from small Kolmogorov scales to large fossilization scales. In stratified natural fluids like the ocean, most of the turbulent kinetic energy is converted to fossil vorticity turbulence and fossil turbulence internal waves. Information about submerged turbulence is beamed by fossil turbulence waves to the sea surface, where it can be detected by remote sensors of sea surface brightness patterns.

Keywords: Turbulence, Fossil Turbulence, Fossil turbulent waves, Remote Sensing, Non-acoustic ASW.

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1 Introduction

The security of the United States depends on an assumption that our SSBN missiles exist on invisible platforms, where SS means submarine to the US Navy, B is ballistic and N is nuclear. Turbulent wakes produced by the passage of submarines are assumed to vanish in short time periods[6] proportional to the overturn time of the turbulent eddies produced, say ten meters divided by one meter per second, or ten seconds. A few seconds is not enough time for the submarine to be detected and endangered. Most oceanographers believe that oceanic turbulence is similarly ephermeral[17]. They are mistaken. Judging by the oceanographic literature, turbulence occurs rarely in the ocean and vanishes without a trace, claims about fossil turbulence to the contrary not withstanding[1,2,3,4]. Fossil turbulence concepts require a narrow definition of turbulence based on the inertial vortex force and a reversed "inverse" of the energy cascades of turbulence and turbulent mixing. The standard L. Richardson poem of turbulence beginning "big whorls …" must be abandoned and rewritten[5]. It is false and misleading.

Thus it must have been a surprise for the US national defense community to see evidence in the official Russian news magazine Ruskaya Gazetta, Figure 1, that traces of previous submarine passage persist in the stratified ocean for days and not just a few seconds. No physical mechanism for the long term detection of submarine or aircraft carrier wakes was included in the article. In a preliminary posting of a 2014 Annual Review of Fluid Mechanics Spedding article about wake detection[6], no reference is made to the term fossil turbulence. Only one article in the history of the Journal of Fluid Mechanics exists with "fossil turbulence" in its title[2]. However, numerical simulations (Diamessis et al.) of a stratified sphere wake[7] show persistent fluctuations for *Nt* periods exceeding 1000. This is over 12 days in most of the ocean relevant to submarines.

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Fig. 1 How can submarine wakes persist and be detected for several days?

Here it is proposed that the claimed persistence of submarine wakes is due to fossil turbulence[5]. The concept of fossil turbulence was first introduced by George Gamov in the 1950s to explain galaxies of stars as manifestations of density fluctuations produced by turbulence in the primordial gas of nucleosynthesis after the big bang, consisting mostly of hydrogen (75%) and helium-4 (25%). The idea was abandoned by Russian cosmologists (eg. Zeldovich and Novikov) when it was discovered that the normalized primordial gas density and temperature fluctuations

$\delta\rho/\rho \sim \delta T/T$ were too small to reflect active turbulent mixing; that is, only 10^{-5} rather than 10^{-1}. Cosmic microwave background spectra from the Planck collaboration show fossils of both big bang and plasma epoch turbulence (see frontispiece journalofcosmology.com volume 23), previously misinterpreted as sonic peaks and harmonics. Powerful evidence of fossil turbulence and fossil turbulence waves are provided by radio telescopes with pulsar sources (see frontispiece J of C volume 21). These produce 11 spectral decades as the great power law on the sky, reflecting predictions of the modern turbulence and turbulent mixing theories used here.

Galaxies are actually fossils of buoyancy and rotationally suppressed turbulence, which develops when large photon viscosity first permits gravitational fragmentation of the primordial plasma[7,8]. The fragmentation begins only 30,000 years (10^{12} seconds) after the big bang at protosupercluster and protosupervoid scales[9]. When the cooling plasma turns to gas at 300,000 years (10^{13} seconds) the gas viscous gravitational fragmentation occurs at the Jeans sonic scale of a million stars and an Earth mass planetary scale, forming the dark matter of galaxies. These fossils of big bang and plasma turbulence have persisted for 13.7 billion years ($>10^{17}$ seconds).

The fragmentation and fossilization process cannot be understood without accepting a narrow definition of turbulence based on inertial vortex forces, where the turbulence kinetic energy cascade always proceeds from the Kolmogorov viscous-inertial scale to larger scales by vortex mergers[8,9]. Most of the mixing of the ocean and atmosphere, and within the self gravitating fluids of astrophysics, astronomy and cosmology, occurs in a fossil turbulence hydrodynamic state. Most of the transport of heat, mass, momentum, and information, in natural fluids is by a complex nonlinear mix of turbulence, gravity, vortex dynamics and fossil turbulence internal waves[10,11,12,13].

2 Theory

To understand how fossil turbulence and fossil turbulence waves permit the remote sensing of submerged submarines, it is first necessary to define turbulence. Turbulence is defined as an eddy-like state of fluid motion where the inertial-vortex forces of the eddies are larger than any of the other forces which tend to damp the eddies out. This is a narrow definition of turbulence, whose mechanism[5] and direction of cascade is illustrated by Figure 2.

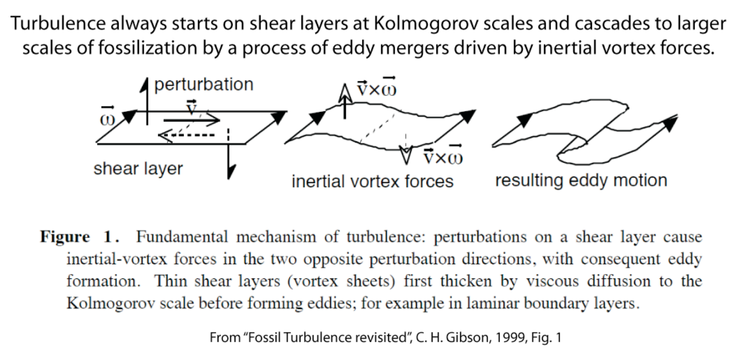

Fig. 2 Fundamental mechanism of active turbulence, driven at Kolmogorov scales by inertial vortex forces to cascade to larger scales by merging of adjacent vortices with the same directions, Gibson (1999, Fig. 1).

As shown in Fig. 2, turbulence by this definition must always cascade from small scales (the Kolmogorov viscous-inertial scale) to large. Adjacent vortices pointing in the same direction induce inertial vortex forces that cause the eddies to merge, increasing the size of the eddy for incompressible fluids. Other forces such as buoyancy will cause the turbulence to fossilize when critical dimensionless ratios are exceeded, such as the Froude number. Hydrodynamic phase diagrams[2] (HPDs) are used to classify hydrodynamic states using microstructure measurements.

Normalized Froude numbers are plotted versus normalized Reynolds numbers. Only rarely is it found in the ocean that a patch of microstructure is turbulent at all scales. Usually the fluid is fossilized at large scales and actively overturning only at the smallest scales[14,15,16]. During the RASP (remote anthropogenic sensor program) experiments, it was necessary to collect tens of thousands of HPDs to adequately characterize the intermittent and patchy transport process.

3 Observations

An array of ships, moorings, drogues, space satellites and scientists was assembled during the RASP experiments, illustrated schematically by Figure 3 from the key referenced paper.

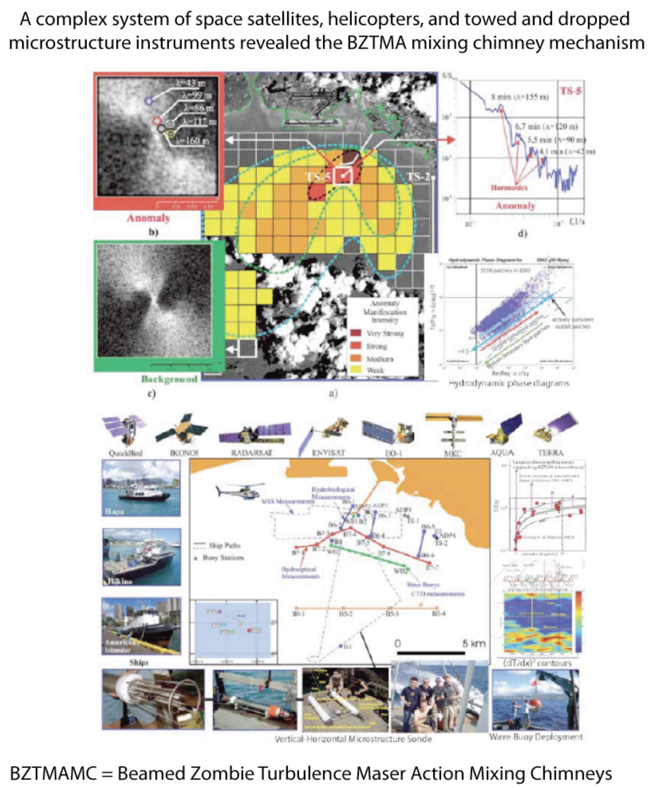

Fig. 3 Remote Anthropogenic Sensing Program RASP, Honolulu Sand Island Municipal Outfall at Sand Island. This is Fig. 1 from SPIE conference paper 6680-33, San Diego 2007 (J of C Vol. 21, Section II, Paper 23).

The RASP experiments were designed to test Russian claims similar to those of Sergey Ptichkin in Fig. 1. As shown in Fig. 3, sea surface brightness detected by remote sensors on satellites, helicopters, and even a hand held camera on the international space station (commanded by one of Valery Bondur's students) were analyzed for anomalies in two dimensional Fourier space for km sized patches. The most intense anomalies concentrated at the outfall, and are attributed to a beamed zombie turbulence maser action mixing chimney mechanism (BZTMAMC)[19]. The mechanism is generic to transport processes in natural fluids such as the stratified ocean[15]. Details of the RASP experiments (2002, 2003, 2004) are at http:// journalofcosmology.com /JOC21/ indexVol21CONTENTS.htm. Manifestations of the outfall never resulted from plume surfacing, as sometimes reported[18].

4 Conclusions

Mechanisms exist in the stratified ocean (Figs. 2 and 3) to permit remote sensing of submerged submarines from fossil vorticity turbulence remnants that persist for many days. Claims in the publication RG.RU (Fig.1) are fully justified by extensive sea tests[19]. Modern turbulence theory and turbulent mixing mechanisms are required. Surface manifestations of submerged turbulence are no longer a mystery[20].

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Turbulence always starts on shear layers at Kolmogorov scales and cascades to larger scales of fossilization by a process of eddy mergers driven by inertial vortex forces.

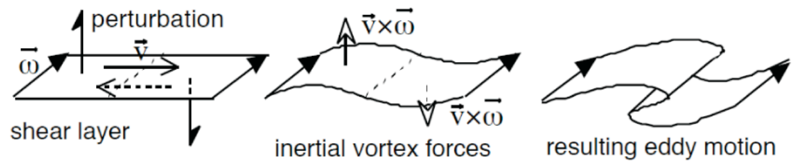
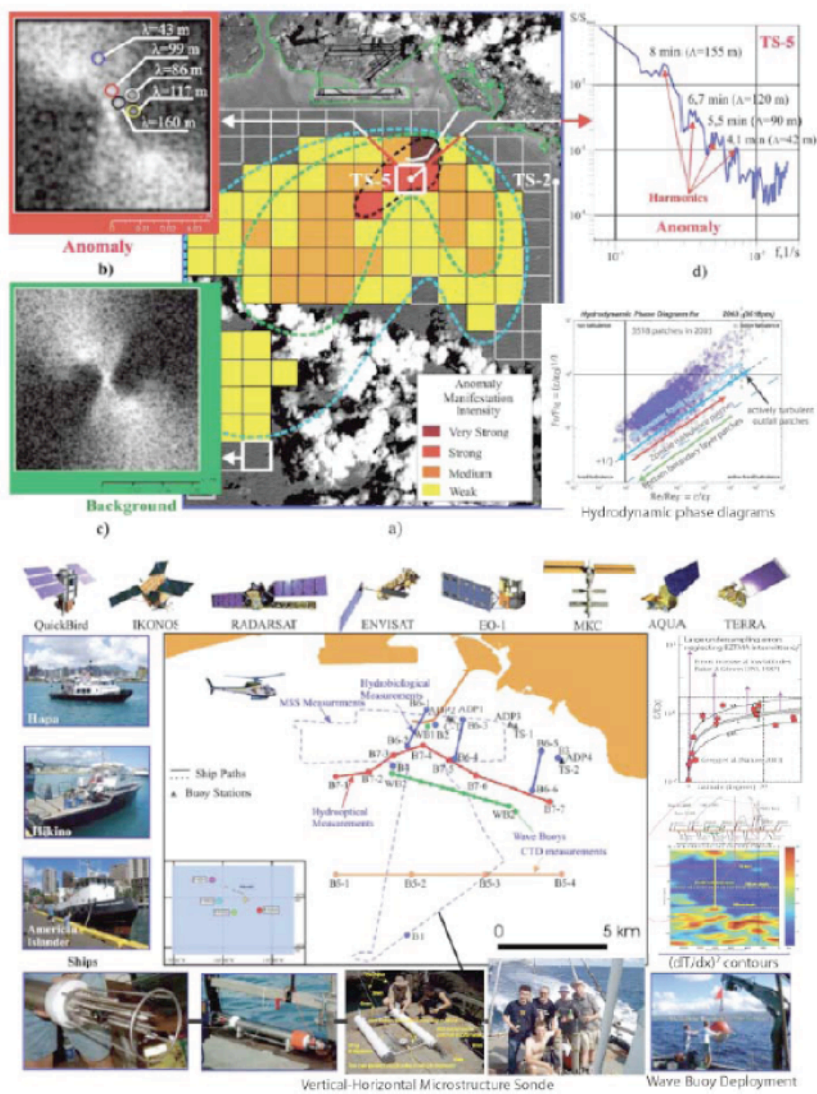


Figure 1. Fundamental mechanism of turbulence: perturbations on a shear layer cause inertial-vortex forces in the two opposite perturbation directions, with consequent eddy formation. Thin shear layers (vortex sheets) first thicken by viscous diffusion to the Kolmogorov scale before forming eddies; for example in laminar boundary layers.

From "Fossil Turbulence revisited", C. H. Gibson, 1999, Fig. 1

A complex system of space satellites, helicopters, and towed and dropped microstructure instruments revealed the BZTMA mixing chimney mechanism



BZTMAMC = Beamed Zombie Turbulence Maser Action Mixing Chimneys

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