Abstracts

Air-sea exchange of gases and particles

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Air-sea exchange of energy, gases and particles are important for most aspects of our environment, from global to microscale and from physical, over chemical to biological aspects. The presentation will seek to summarise the different processes that are responsible for different types of air-sea exchange and also try to describe and illustrate where and how the different processes are important. The aspects considered will range from meteorology and oceanography, nutrient transport and eutrofication of coastal waters, Green house gas balances, production marine aerosols and condensation nuclei, to epidemiology.

Statistical models of wind events to determine turbulence in water

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Turbulence influences planktonic communities at different scales from generation to dissipation. Many experimental studies have recently been done to determine the effects of small-scale turbulence on plankton, but it is difficult to state the relevance of the findings since there is little unbiased information on turbulence levels in the sea. We used wind velocity data series from several meteorological stations located along the Catalan coast to estimate the spatial and temporal variability of small-scale turbulence. Using a peaks-over-threshold approach, we developed statistical models to assess frequency of wind events, as a function of their persistence and mean speed value. These models showed higher frequencies of intense events in locations and seasons with higher mean wind values. Geographical differences are larger than seasonal differences in wind event frequency and persistence, due to the strong effect of local relief. These statistical models developed for wind events combined with empirical relationships between wind and turbulence are a tool to estimate the occurrence and persistence of turbulent events in the sea.

Larval settlement as a function of local hydrodynamics and the role of instantaneous forces in a turbulent boundary-layer

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Based on patterns of larval settlement in the field, we propose that turbulent flow structures near the substrate surface determine available time for initial larval adhesion based on critical levels of hydrodynamic forces leading to detachment. In a study of turbulent flow structures in the near-bed layer with ADV, hot film anemometer and PIV we measured periods of stress relaxation and estimated peak drag and lift forces. From flume data on the temporal distribution of instantaneous forces we tested hypotheses of critical periods of low forces and frequency of peak forces as mechanisms explaining field correlations between larval settlment and local hydrodynamics.

Hydrodynamics and the persistence of adult populations

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Among marine invertebrates a life cycle containing a larval stage is common. Because of the advective powers of water the exchange of larvae between distant populations/areas has been hypothesised to be important to the dynamics of adults. Research in this are has been focused on diffusion models and larval pool ideas. However, in recent years Lagrangian approaches have proliferated. I present a 0D and a 2D-Lagrangian model of larval dispersal in the Adriatic Sea. These two models are investigated for dependencies in larval transport of the behaviour of larvae.

A detailed representation is better than a coarse representation, but to what extent? Behaviour has great influence on dispersal distances and we are still unsure of how behaviour of larvae may enhance or diminish the hydrodynamic signal. Model predictions and field distributions have yet to be compared. Do they coincide? If they do not, then what are our options?

Mixing and reaction efficiency in closed basins

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We made a numerical study of mixing efficiency of inert transport and reaction efficiency of active transport in a closed basin. We focus our attention on laminar flows. In the case of inert transport the mixing properties of the flows strongly depend on the details of the lagrangian transport. We also study the reaction efficiency in the closed domains, i.e., starting with a little spot of product we compute the time needed to complete the reaction in the container. We found that the reaction efficiency is not so strictly related to the mixing properties of the flow. In particular reaction seems to act as a "dynamical regulator".

Towards an integrated understanding of turbulence as a modulating factor in marine planktonic systems

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In aquatic systems, interactions between mechanical energy and biological activities occur at multiple scales. Mechanical energy returns nutrients to the photic zone, controlling primary production. At smaller scales mechanical energy is, in general, characterised by turbulent flow. Theoretical and experimental studies have pointed out the importance of small-scale turbulence modulating bottom-up processes (varying nutrient flux to the cells) and top-down processes (changing contact rates between predator andprey), and favouring particular life forms.

Turbulence affects planktonic food webs at different scales and in different directions and therefore in order to define a conceptual frame of interactions between turbulence and plankton it is necessary to combine information from numerous sources. We have compiled studies from the last 10 years devoted to examine the effects of turbulence on planktonic organisms and processes. By comparing the results of the different experiments, we have identified general trends as well as particular responses crucial to construct the conceptual frame. In this presentation we will show our findings and discuss their importance to identify thresholds for plankton yields and to improve our understanding of biogeochemical fluxes.

Larval fish visual feeding and turbulence

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Fishes are mainly depending on vision to detect their prey. Larval fish gradually develop their visual abilities from non-functional to quite accurate during their early life history. Their visual range, i.e. the distance at which prey is detected, is sensitive to the ambient light-environment, and will vary strongly with depth. There is a strong interaction between light and turbulence on both the positive effect on prey encounter rates, and the negative effect (as seen from the point of view of a larval fish) on prey escape probability after an encounter event. I will present some models of these processes, and the implications this have on larval habitat selection, growth and feeding rates. In addition, I will present an observation made during a cruise to the northern Norwegian Sea last spring. We observed the total erosion of a diatom bloom during two days of strong winds, while sampling at large depths (down to 500 m) revealed significant amounts of greenish material below the mixed layer. This suggests that turbulence-generated aggregation of algal cells facilitated rapid sinking and export of carbon to deep waters.

A field study of turbulence and fish larvae in a region with swell-induced turbulence

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In 1995 and 1996 field investigations were conducted in the areas for first-feeding larval cod in Lofoten, Norway. Direct measurements of turbulence were conducted from an underwater tower 6 m above the bottom for one week each year. The investigation site was a large shallow (20-30 m deep) bank. The area was subject to long incoming swells, which intermittently got unstable in this shallow region. The instruments resolved the patchiness of the swell generated turbulence, which gives a unique possibility to study this process.

Sampling of hydrography, zooplankton and cod larvae were conducted simultaneous from a nearby ship. In this talk I will present the investigation, with special focus on the swell induced turbulence. In addition I will try to relate the generated turbulence to food uptake and energetic of cod larvae.

Monte Carlo simulations of predator - prey models - an example of embarrassingly parallel problem

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Biological and ecological modeling is a fast growing subject in the last decades. It is also becoming more and more computer intensive. Consequently, we are continuously forced to use more powerful computing systems.

Recently, personal computer clusters became very promising technique for building up cheap, easy-to-use, high performance "supercomputers". These "supercomputers" can be used for everything from simple data mining to weather modeling at truly outstanding speeds. The idea behind clusters is to decompose a large task into smaller ones to be performed simultaneously (i.e. in parallel) on cluster computers.

Monte Carlo (MC) simulations are often used in modeling predator-prey systems. These simulations are an example of "embarrassingly" parallel problems, i.e. problems that can be divided into completely independent parts. Such problems are relatively easy to parallelize.

Nonlinear scenarios for planktonic dynamics in chaotic flows

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Satellite images of sea surface chlorophyll reveal complex phytoplankton patterns with distinct filamental features. Strong inhomogeneity and intermittency persist all the way down to small scales. The influence of ocean turbulence on these features, and in other nonbiological advected quantities such as temperature, is evident but poorly understood.

Given the disparity of scales and the variety of processes involved, it is by now clear that no single mechanism can reasonably explain all the available observations of plankton patchiness. Nevertheless, progress in scenario building, i.e. the identification of minimal models leading to particular qualitative features of observed data, is needed to advance in the classification and understanding of complex plankton dynamics.

In this talk I will review results obtained during the last years that establish two particular scenarios for the dynamics of plankton inhomogeneity. In both of them, the only ingredient that is kept from ocean turbulence is the characteristic Lagrangian chaos in fluid particle trajectories. Two different types of biological dynamics are considered. First, we study predator-prey models with tendency to stable coexistence at concentration values fixed by nutrient sources. Filamentary and multifractal structures appear when stretching by the flow is fast enough. This has consequences in observables such as power spectra of concentration variances. Second, we investigate the effect of chaotic advection on plankton models of the excitable type. These have been suggested to capture some aspects of plankton blooms. The excited state (high phytoplankton concentration) propagates along filaments and synchronous excitation of large closed domains is possible in some parameter range. In open flows, despite the continuous loss of plankton and the intrinsic transient character of excitable dynamics, permanent patterns of excitation can persist indefinitely in the system. Strong mixing however can suppress excitation by diluting perturbations below a threshold.

Lagrangian statistics in turbulence

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Lagrangian acceleration in turbulence is one of the most intermittent phenomenon in nature. At the typical Reynolds number of laboratory experiments, the instantaneous acceleration can easily attain values 80 times the root mean square value.

In this talk I will review the problem of turbulent Lagrangian statistics on the basis of a set of high resolution direct numerical simulations. High resolution Lagrangian statistics is obtained in a range of time spanning more than three decades, from less than a tenth of the Kolmogorov timescale up to one large-eddy turnover time. Acceleration intermittency is found to originate from the trapping of Lagrangian tracers in strong vortices at the Kolmogorov scale.

Bio-Mixing generated by benthic filter-feeders

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Benthic (bottom-dwelling) filter-feeding animals such as polychaetes, ascidians and bivalves live from micro-organisms (such as phytoplankton) suspended in the sea water at low concentration. For typical benthic populations, the area specific filtration rate amounts to $1-10\ m^3$ per m^2 per day, or more, which may have a pronounced grazing impact on the phytoplankton biomass in many shallow marine areas. During periods with stagnant water this leads to near-bottom phytoplankton depletion. For this process, transient concentration distributions have been studied experimentally and numerically, and the variation of effective diffusivity above the sediment has been inferred. It is high ($0.3 - 150 \times 10^{-6}\ m^2/s$) close to the bottom due to the agitation (bio-mixing) produced by inhalant and exhalant (jet) flows generated by the animals. This significant bio-mixing is believed to be also important during periods of sea currents, which generate turbulent benthic boundary layer (BBL) flows. Flume studies of velocity, turbulence and concentration in BBL over a bank of mussels, in progress at Institut für Meeresbiologie, Rostock University in collaboration with University of Southern Denmark, reveal the extent of bio-mixing for 3 values of current. These results will be discussed in relation to the basic flows associated with bio-mixing.

Particle retention in flow over seagrass canopies

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Seagrasses are species that grow along the coast forming one of the most interesting and important ecosystems. In particular, Posidonia oceanica is one of the most characteristic seagrasses of the Mediterranean sea covering about 2% of its surface ($5 \times 106\ km^2$), 750 km^2 just around the Balearic islands. The only presence of P. Oceanica is known to be responsible of increasing by a factor of 3 the biomass production, thus being essential to the trophic chain. Furthermore, the network structure of its rizhome prevents soil erosion due to tidal and marine currents. Canopies form barriers that protect the shallow water marine environment, the coastline, and are responsible of the formation of beaches. It is known that seagrasses attenuate currents and waves and, as a result, tend to accumulate organic and inorganic particles in the canopy. The purpose of our research is to understand the effect of the canopy on the fluid flow, the formation and propagation of wave-like oscillations monami, the particle retention mechanism through physical binding to the leaves (due to adhesion to exopolymeric substances excreted by epiphytes), or by the loss of energy (by hitting a leave and subsequent redirection towards the sediment surface), and its capacity to act as an efficient filter. Field experiments of particle trapping rates in flumes by direct tracing of individual particles, and fluid flow measurements with an acoustic doppler velocimeter, will combine with theoretical models to reproduce the fluid flow inside the canopy and the particle retention. We will present the ongoing work and the different strategies to face the problem.

Summary of field experiments on the effect of turbulence on fish larval feeding

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Field evidences of effects of small-scale turbulence on plankton contact rates and feeding are scares. The major reason is that turbulence is only one of a number of processes influencing feeding in plankton organisms. In order to measure the effects of turbulence detailed knowledge about the organisms is needed both with respect to their specific behavior and dependence on other environmental parameters, biotic as well as abiotic. In the late 1980s and early

1990s comprehensive field investigation were conducted in areas for first-feeding larval cod in Lofoten. These studies enabled us to reveal the effects of turbulence on larval cod feeding on copepod nauplii, and it was the first documentations from the field. In this presentation I review the particular sampling technique that was developed by the Cod larvae projects at Institute of Marine Research 10 years earlier and that made it possible to conduct the field-based turbulence studies.

A model of plankton dynamics coupled with a LES of the surface mixed layer

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The dynamics of phytoplankton populations are not only determined by biological processes such as growth/mortality rates, nutrient levels and predator-prey interactions, but by the distributions of the micro-organisms, which are governed by the physical structures and motions of the ocean. These biological-physical interactions take place over a wide range of different scales, e.g. nutrient rich upwelling gyres over many kilometres are associated with high phytoplankton concentrations, whilst individual predator-prey encounters are governed by turbulent motion on the scale of millimetres. In this presentation the influence of physical processes on a simple ecosystem at intermediate scales (tens of metres), namely those associated with the large-eddy structures of turbulence in the surface mixed layer, will be examined. The objective of the work will be to see what characteristics of the water motion are associated with high levels of phytoplankton activity, and how these are correlated with local nutrient and predatory zooplankton concentrations.

The basis of the mixed layer model is formed by a LES code, which integrates a spatially filtered form of the Navier-Stokes equations. The applied boundary conditions are horizontal periodicity, whilst at the surface a specified wind stress is imposed in the positive x direction. One unusual feature is the incorporation of a "vortex force" term, brought about by a coupling of the Stokes-drift velocity associated with surface waves, with the local vorticity. This "vortex force" is thought to be the mechanism underlying the formation of Langmuir circulations, a series of near surface counter rotating roll cells (called Langmuir cells), aligned roughly in the wind direction. Associated with these cells are upwelling and downwelling zones in which levels of vertical mixing are greatly increased. It has been speculated that such enhanced mixing rates, characteristic of "Langmuir turbulence" will play a significant role in stimulating planktonic activity. The presentation will examine results derived from simulations with and without Langmuir circulations.

The biological model is formed from three coupled advection-diffusion equations for nitrate N, phytoplankton P and zooplankton Z of the form:

$\partial N/\partial t + \mathbf{U}\cdot\nabla N = D_N\nabla^2 N$ – uptake by phytoplankton + recycled from phytoplankton growth inefficiency,

$\partial P/\partial t + \mathbf{U}\cdot\nabla P = D_P\nabla^2 P$ – growth (based on light and N levels) – grazing loss (based on Z concentration),

$\partial Z/\partial t + \mathbf{U}\cdot\nabla Z = D_Z\nabla^2 Z$ + grazing uptake (based on P concentration) - mortality rate,

where $\mathbf{U}$ is the instantaneous (LES) turbulent velocity field. Full details of the various source/sink terms will be discussed in the talk.

Vertical profiles of mean, variance, vertical flux and correlations between the various scalar fields, averaged over time and horizontally, will be presented. Also the nature of the instantaneous evolution of the planktonic concentrations will be examined. Particular attention will be paid to the characteristics of those flow features that correlate to high levels of phytoplankton growth and patch formation.

Physics in the Brain

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A striking development in today's science is the increased used of mathematical modelling in biological sciences. Good mathematical descriptions of signal processing in single nerve cells have been developed, and as a consequence mathematical neuroscience has become a particularly active discipline attracting many physicists, mathematicians and computer scientists.

The fantastic properties of the brain are due to an intricate interplay between billions of neurons connected in a complex network. A central challenge is to understand such network behaviour and establish connections between known properties at the microscopic level (single nerve cells) and measurements of brain activity at the macroscopic systems level (using, for example, MEG, EEG, PET, or fMRI).

In the seminar several examples of mathematical modelling of biological neural networks will be presented. Results from a combined experimental and theoretical project aimed at studying cortex at the intermediate, mesoscopic level (cortical microcircuit involving 10-100.000 nerve cells) will also be given.

"Biased" random walks

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Micro organisms, such as bacteria or other aquatic micro organisms, can be embedded into a spatially inhomogeneous distribution of food. It might be that this is dissolved in the surrounding environment. In such cases, it might be possible for the micro organisms to sense gradients in the distribution [1]. If, however, the prey consists of a diluted distribution of individual particles, or even smaller organisms, it is unlikely that gradients can be distinguished directly by sensing the local environment. In such cases, it might be possible that simple adaptive behavior can make the organism move [2], on average, in a favorable direction. We discuss such a model, with a memory of "one step", which can readily be formulated in a standard form, similar to a "biased" random walk. Results from Monte Carlo simulations will be presented.

[1] R. Thar & M. Kühl, Bacteria are not too small for spatial sensing of chemical gradients; An experimental evidence. Proc. Natl. Acad. Sci. USA (PNAS), **100**, 5748-5753 (2003)
[2] D. F. Blair, How bacteria sense and swim. Ann. Rev. Microbiol. **49**, 489-522 (1995)

Characteristics of solute plumes trailing particles in a turbulent water column

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Many aquatic organisms - from bacteria to crustaceans - use chemical plumes released by sinking particulate organic material either directly as a food source or as a signal to find potential food items (marine snow aggregates, fecal pellets). The characteristics of these plumes, their length, volume and cross sectional area, are important metrics for the encounter rate between searching copepods, and detrital material. This work examines how these vary with turbulence. Total plume length appears to be invariant to turbulent shear rate, although plume volume and cross section do decrease strongly with increased turbulence. Turbulence can also break a plume into multiple segments. The length of the segment connected to the particle (the first unbroken segment) tends to be about a half of the total plume length, as well as containing about half of the total plume volume and cross sectional area. Despite the complexity of the processes involved, these relationships can be described by relatively simple functions that are revealed both empirically through modelling and through theoretical analysis. The critical parameter is γT_0^*, being the product of the average turbulent shear rate γ and the diffusive time scale – the length of time a plume would last in calm water. The results highlight the ecological differences associated with different turbulence intensities as a function of depth in the water column.

Flow modes and modulation of the water currents produced by free-swimming calanoid copepods

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A concept of modulation of basic flow modes is proposed to understand the unsteady flows created by a copepod which changes its swimming behavior, and therefore, displays a sequence of different swimming behaviors during a time period of up to tens of seconds. The basic flow modes are referred to the steady flow fields of different patterns associated with several basic steady translational swimming behaviors, i.e., free sinking, partial sinking, hovering, vertical swimming upward, and horizontal swimming backward or forward. By applying a time-varying propulsive force, these basic flow modes can be temporally modulated to create unsteady flows based on observed time histories of parameters describing the copepod's unsteady swimming behavior. Based on this concept, a hydrodynamic modeling study has been carried out and successfully reproduced the observed swimming event of a copepod. It is shown that the modulation enables a copepod (1) to control the unsteady water currents it creates around its body, and (2) to manipulate precisely the trajectories of algal particles entrained in the currents over long time duration. This process may be energetically more efficient than exerting a constant propulsive force onto the water to create a constant feeding current due to the no-need to scan an extra large amount of water within which there are no valuable food items. This study reveals a complex interplay among a copepod's unsteady free-swimming behaviors,

the unsteady flows created by the copepod at its body scale, and the resulting trajectories of entrained algal particles, over the time duration of up to tens of seconds.

Advances in particle tracking in turbulent flows

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Particle tracking experiments have recently inspired much work on Lagrangian properties of turbulence and its applications to biological systems. At Risø we have used the technique to study relative dispersion of pair of particles and to test various hypotheses about the relation between Lagrangian versus Eulerian statistics and temporal versus spatial statistical quantities. On the biological side, we have used the experiment to simulate the flow of prey to passively advected predator in the upper turbulent parts of the ocean. The experiment at Risø have been completely rebuilt with new cameras, computers, optics and light source. Furthermore, we have incorporated the advanced tracking software of ETH in Zürich. As data from this new experiment materializing, we are now able to take a more detailed look at the flow. The preliminary measurements include velocity derivatives, such as vorticity and strain, and acceleration, both one- and two-point statistics.

Lagrangian measurements of vorticity dynamics in turbulent flows

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A recent experimental break through allows to measure velocity derivatives in a Lagrangian way in turbulent flow. Lagrangain recordings of velocity derivatives, among other things, are helpful to describe what any small object which is following a trajectory of a turbulent flow is experiencing. Along these trajectories such small objects will be swirled around and - through the acting of the straining field - they will also be deformed. The velocity derivatives fully describe both, the swirling and the deformation, of such small objects, e.g., a fluid particle.

In this presentation I will briefly introduce the terms "vorticity" and "strain" which are responsible for the "swirling around" and the "deforming" of fluid particles. From this we will move on to how velocity derivatives can be measured in the experiment. The measurements are performed by applying the Three Dimensional Particle Tracking Velocimetry (3D-PTV) technique to an electromagnetically forced flow with low Reynolds number. The crucial step that is allowing access to velocity derivatives, is a weighted interpolation procedure. A few results, which support the accuracy of the presented method, are shown before we finally focus on the actual results that can be derived.

First of all, we show the most important ingredients for the self amplifying nature of turbulence. Both, the field of vorticity and the field of strain have closed, positive feedback loops, of which the governing terms can be measured. In other words vorticity and strain have self-production. Secondly, we show how there exists also a dynamical mechanism which is able to dampen this process. Further, from our results on swirling budget terms, we infer that there is no pointwise balancing of production and viscous reduction of swirling strength and that the role played by viscosity must be of utmost importance and much more subtle than "just" dampening turbulence dynamics.

Finally we touch on how passive objects, in our case material elements, behave in such flow dynamics. Again, these material elements can be followed in time experimentally. They are directly related to important mixing and dispersion properties of turbulent flows.

Multiple-scale analysis and renormalization for pre-asymptotic scalar transport

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Pre-asymptotic transport of a scalar quantity passively advected by a velocity field formed by a large-scale component superimposed to a small-scale fluctuation is investigated both analytically and by means of numerical simulations. Exploiting the multiple-scale expansion one arrives at a Fokker–Planck equation which describes the pre-asymptotic scalar dynamics. Such equation is associated to a Langevin equation involving a multiplicative noise and an effective (compressible) drift. For the general case, no explicit expression for both the effective drift and the effective diffusivity (actually a tensorial field) can be obtained. We discuss an approximation under which an explicit expression for the diffusivity (and thus for the drift) can be obtained. Its expression permits to highlight the important fact that the diffusivity explicitly depends on the large-scale advecting velocity. Finally, the robustness of the aforementioned approximation is checked numerically by means of direct numerical simulations.

3D Particle Tracking of turbulent flows at Cornell

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High speed cameras are utilized in a "French washing mashine" in order to detect 3D turbulent motion on the smallest scales. By having a relatively high particle seeding, it is possible to obtain both single and multiple particle statistics. Both water and polymer flows have been studied. Recent advances from the experiments will be presented.

Possible applications of marker-and-cell technique to predator-prey simulations

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The main idea is to present new possible applications of the Marker-and-Cell (MAC) method to predator-prey systems. Historically, MAC technique has been applied to numerical simulations of an incompressible transient fluid flow with free surfaces. Markers (massless particles) were used only to treat fluid/vacuum interfaces (free surfaces of the fluid). We found that, by using markers, it is possible to calculate trajectories of every single particle in the flow. In

the presentation, the MAC method and some ideas of its use in simulations of predator-prey systems will be explained.

How long can left and right handed life forms coexist?

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Reaction-diffusion equations based on a polymerization model are solved to simulate the spreading of hypothetic left and right handed life forms on the Earth's surface. The equations exhibit front-like behavior as is familiar from the theory of the spreading of epidemics. It is shown that the relevant time scale for achieving global homochirality is not, however, the time scale of front propagation, but the much longer global diffusion time. The process can be sped up by turbulence and large scale flows. It is speculated that, if the deep layers of the early ocean were sufficiently quiescent, there may have been the possibility of competing early life forms with opposite handedness.

Numerical modeling of predator-prey encounters in turbulent waters

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The fluxes to small surfaces of different shapes, moving with the flow are studied by direct numerical simulations [1]. While the relevant laboratory experiment [2] refers to decaying turbulence, the numerical simulations are here driven uniformly over space. A reference case with spherical surfaces is used for comparison between the two realizations of the turbulence. With the large amount of data available in the simulations, it was possible here to make detailed comparisons with results from theoretical studies. We could analyze also more complicated surfaces, for instance small "cones", with different opening angles, with the cone axis aligned with the local velocity vector at all times. By use of such surfaces, we believe it to be possible to model the field of vision of small predators relatively accurately. We analyse the flux-scaling for varying scale size of the cones, with fixed opening angle. It is demonstrated that the scaling arguments from [2] remain correct, and a change in shape only affects a numerical coefficient. An empirical scaling law for varying opening angle of the cones, with fixed length of the cone axis, is also obtained. The analysis also indicates simple means for aquatic microorganisms to distinguish the direction of the local velocity vector, even when they are passively following the flow.

[1] L. Biferale, G. Boffetta, A. Celani, A. Lanotte and F. Toschi, Particle trapping in three-dimensional fully developed turbulence. Phys. Fluids **17**, 021701 (2005).

[2] J. Mann, S. Ott, H. L. Pécseli & J. Trulsen, Predator–prey encounters in turbulent waters. Phys. Rev. E. **65**, 026304 (2002)

Predator-prey encounters in turbulent waters

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With reference to studies of predator-prey encounters in turbulent waters, we demonstrate the feasibility of an experimental method for investigations of particle fluxes to an absorbing surface in turbulent flows. We analyze data from a laboratory experiment, where an approximately homogeneous and isotropic turbulent flow is generated by two moving grids. The simultaneous trajectories of many small neutrally buoyant polystyrene particles were followed in time. Selecting one of these to represent a predator, while the others are considered as prey, we obtain estimates for the time variation of the statistical average of the prey flux into a suitably defined "sphere of interception". The variation of this flux with the radius of the sphere of interception, as well as the variation with basic flow parameters, are well described by a simple scaling-law, in particular for radii smaller than a characteristic length scale for the turbulence.

In-plume concentration fluctuations and self-similarity

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Fast-response concentration data from dispersion experiments with continuous surface releases have been analysed, and striking self similarities in the spatial profiles of concentration fluctuations are identified. The cross-wind mean profile, analysed in a moving frame of reference following the centre of the meandering plume, deviates from the expected Gaussian shape. This deviation is now theoretically explained by a model, in which the diffusion coefficient is defined by two length scales. With appropriate scaling of widths and centre-line values, the observed profiles of higher-order statistical moments of concentration fluctuations are shown to coincide with the mean profile. An empirical relation between the scaling widths for these profiles is presented. It is shown that, with moving-frame analysis, the centre-line fluctuation intensity has little dependence on friction velocity or atmospheric stability.

Nonlinear growth models with age structure

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Some investigations of nonlinear growth models with age structure and discrete time will be described, which exhibit a plethora of interesting patterns of bifurcations and nonlinear behavior. Our latest finding is a class of models with semelparity, for which synchronization occurs, i. e., the whole population collects into a single age class.