Environmental and Geophysical Fluid Dynamics
Dynamique des fluides en géophysique et en science de l'environnement
(Org: **Francis Poulin** (Waterloo))

GUALTIERO BADIN, University of Hamburg
Hydrodynamic Nambu Brackets derived by Geometric Constraints

A geometric approach to derive the Nambu brackets for ideal two-dimensional (2D) hydrodynamics is suggested. The derivation is based on two-forms with vanishing integrals in a periodic domain, and with resulting dynamics constrained by an orthogonality conditions. As a result, 2D hydrodynamics with vorticity as dynamic variable emerge as a generic model, with conservation laws which can be interpreted as enstrophy and energy functionals. Generalized forms like surface quasi-geostrophy and fractional Poisson equations for the stream-function are also included as results from the derivation. The formalism is then extended to a hydrodynamic system coupled to a second degree of freedom, with the Rayleigh-Benard convection as an example. This system is reformulated in terms of constitutive conservation laws with two additive brackets which represent individual processes: a first representing inviscid 2D hydrodynamics, and a second representing the coupling between hydrodynamics and thermodynamics. The results can be used for the formulation of conservative numerical algorithms that can be used, for example, for the study of fronts and singularities.

WALTER CRAIG, McMaster University
Birkhoff normal forms for water waves

Abstract: A normal forms transformation for a dynamical system in a neighborhood of a stationary point retains only the significant nonlinearities, eliminating inessential terms. It is well known that the equations for water waves can be posed as a Hamiltonian dynamical system, and that the equilibrium solution represents an elliptic stationary point. This talk will discuss the Birkhoff normal forms for this system of equations in the setting of spatially periodic solutions. Results include the regularity of the normal forms transformations, and the dynamical implications of the normal form. This is joint work with Catherine Sulem (University of Toronto).

MICHAEL DUNPHY, University of Waterloo
Internal tide generation with a background shear current

This work looks at internal tide generation by tidal flow over topography in the presence of a surface trapped background current. We use a 2D non-hydrostatic model to conduct numerical simulations at various strengths of background current. An energy budget analysis of the results reveals that while the generation rate is unchanged by the background current, the upstream energy flux is increased at the expense of reduced downstream energy flux. Lastly we consult the Taylor-Goldstein equation for insight in constructing an explanation for the asymmetric energy flux.

LIV HERDMAN, Stanford University and University of Waterloo
Heat balances and thermally-driven lagoon-ocean exchanges on a tropical coral reef system (Moorea, French Polynesia)

The role of surface and advective heat-fluxes on buoyancy driven circulation was examined within a tropical coral reef system. Measurements of local meteorological conditions as well as water temperature and velocity were made at six lagoon locations for two months during the austral summer. We found that temperature rather than salinity dominated buoyancy in this system. The data were used to calculate diurnally phase-averaged thermal balances. A one-dimensional momentum balance developed for a portion of the lagoon indicates that the diurnal heating pattern and consistent spatial gradients in surface heat fluxes creates a baroclinic pressure gradient that is dynamically important in driving the observed circulation. The baroclinic and barotropic pressure gradients make up 90

NICHOLAS KEVLAHAN, McMaster University
Compressive sampling for energy spectrum estimation of turbulent flows

Recent results from compressive sampling (CS) have demonstrated that accurate reconstruction of sparse signals often requires far fewer samples than suggested by the classical Nyquist–Shannon sampling theorem. Typically, signal reconstruction errors are measured in the ℓ^2 norm and the signal is assumed to be sparse, compressible or having a prior distribution. Our spectrum estimation by sparse optimization (SpESO) method uses prior information about isotropic homogeneous turbulent flows with power law energy spectra and applies the methods of CS to 1-D and 2-D turbulence signals to estimate their energy spectra with small logarithmic errors. SpESO is distinct from existing energy spectrum estimation methods which are based on sparse support of the signal in Fourier space. SpESO approximates energy spectra with an order of magnitude fewer samples than needed with Shannon sampling. Our results demonstrate that SpESO performs much better than lumped orthogonal matching pursuit (LOMP), and as well or better than wavelet-based best M-term or $M/2$-term methods, even though these methods require complete sampling of the signal before compression.

PAUL KUSHNER, Dept. of Physics, University of Toronto
Decomposing atmospheric planetary waves into standing and travelling components

A classical approach to spectral analysis of atmospheric spatio-temporal signals involves separating atmospheric disturbances into standing and travelling zonal wave components. Such a decomposition is motivated empirically by observations of the circulation being dominated by standing or propagating wave patterns, but is complicated by the fact that standing and travelling wave harmonics are not orthogonal. In a study led by O. Watt-Meyer, we have revisited classical methods of standing-travelling signal decomposition to explicitly account for the covariance between the two parts and more clearly identify when wave patterns are dominated by standing or travelling waves. When applied to wintertime Northern Hemisphere circulation, we find that standing planetary waves in the upper troposphere and stratosphere explain the largest portion of the variance at low frequencies. Standing waves tend to constructively and destructively interfere with the climatological stationary wave, suggesting that standing waves contribute to a linear interference effect in wave mean-flow interactions that has been shown to be an important part of stratosphere-troposphere coupling.

KEVIN LAMB, University of Waterloo
Shoaling Internal Solitary Waves in the South China Sea

The interaction of the barotropic tide with Luzon Strait topography generates westward propagating internal bores and solitary waves that can have amplitudes of O(200) m. These waves eventually shoal and dissipate in the north-western South China Sea. Numerical simulations of the shoaling of internal solitary waves at the site of the Asian Seas International Acoustic Experiment have been undertaken to investigate the sensitivity of the shoaling to a variety of environmental factors including the bathymetry, stratification, effects of rotation and viscosity. Over the slope secondary solitary waves and mode-two wave packets are generated before viscous effects become important in shallow water on the shelf.

FRANCIS POULIN, University of Waterloo
Simple Models of Oceanic Fronts

There are many physical processes that transfer energy between different length scales in the oceans. In this talk, we investigate mechanisms through which energy cascades from the mesoscale $O(100\,km)$ to the submesoscale $O(10\,km)$ for oceanic fronts in a reduced gravity shallow water model. One possibility is that linear instabilities can produce energy directly at the small scales. A second is that the direct energy transfer occurs in the nonlinear regime after the perturbations become mature.

This investigation is done using two distinct idealized profiles for an oceanic front. The first profile has a interfacial depth that is a smooth hyperbolic tangent profile and is an extension of the piecewise constant Potential Vorticity profile studied in Boss, Paldor and Thompson (1996). By considering a range of minimum depths, we find that the most unstable mode exists in a one-model and does not need two layers, as previously speculated. Also,we cannot confirm the existence of a secondary instability at smaller length scales due to a gravity-vortical wave instability. The second is the parabolic double front from Scherer and Zeitlin (2008). We find more unstable modes than previously presented and also categorize them based on the mode number. We also study the nonlinear evolution of these oceanic fronts and determine that vanishing layer depths have significant effects on the unstable dynamics that arise. Our results suggest that the nonlinear dynamics of a front can be very efficient at generating submesoscale motions.

MAREK STASTNA, University of Waterloo
Swimming Plankton: Limit cycles and the effect of intrinsic vs extrinsic noise

Recent literature suggests that on fine scales the spatial distribution of plankton in the coastal oceans is profoundly affected by plankton swimming behaviour. Since the variety of swimming behaviour reported in the literature is extensive, and at times contradictory, we set out two relatively simple goals for our study. First, we wanted to identify simple flow-swimming behaviour combinations for which the resulting particle paths were qualitatively different from those due to either flow or swimming on their own. Second we wished to differentiate between two types of stochastic perturbations, namely extrinsic perturbations modelled by Brownian motion and intrinsic perturbations due to differences between individuals. We model the latter as varying the critical shear rate that triggers swimming motion, and find that while extrinsic noise "smears" limit cycles so that any one particle does not follow an exact limit cycle, intrinsic noise alters the shape of the resulting limit cycles but still allows individual particles to follow closed paths. Finally, we discuss how internal solitary wave-induced flows alter the distribution of swimming particles, and find that a combination of extrinsic noise and swimming to maintain a given light level leads to significantly enhanced number density at the rear of the wave, something that could be exploited by higher predators.

JACQUES VANNESTE, University of Edinburgh
Interactions between near-inertial waves and mean flow in the ocean

Wind forcing of the ocean generates a spectrum of inertia-gravity waves that is sharply peaked near the local inertial (or Coriolis) frequency. The corresponding near-inertial waves (NIWs) are highly energetic and play a significant role in the slow dynamics of the ocean at large and mesoscales. In order to examine this role, we use generalised-Lagrangian-mean theory to derive a new model that captures the two-way interaction between NIWs and mesoscale motion. This model couples the Young & Ben Jelloul (1997) model of NIWs with a quasi-geotrophic model in which the wave effect arises through a modification of the potential-vorticity-inversion relation. Simple arguments based on the new model's conservation laws and confirmed by numerical simulations suggest that NIWs provide a significant energy sink for the mesoscale flow. (Joint with Jin-Han Xie.)

MICHAEL WAITE, University of Waterloo
The spectral kinetic energy budget in dry convective turbulence

Over the last few years there have been several attempts to explain the atmospheric kinetic energy spectrum using turbulent inertial subrange ideas. However, several meteorological phenomena have the potential to directly inject kinetic energy, complicating the inertial range picture. In this talk, we consider the effect of surface buoyancy fluxes. High-resolution large eddy simulations of dry convective boundary layers will be presented, and the various terms in the spectral kinetic energy budget will be analyzed. A broad heat flux spectrum develops, causing the energy spectrum to be shallower than it would otherwise be. Only at very high resolutions (grid spacings of 5 m) does an inertial range begin to emerge. This is work with James Sandham (University of Waterloo).