

of how AAIW forms and what role the ACC plays remains a puzzle. The difficulty in examining the formation of AAIW is the many nonlinear process involved at different scales. It's fairly clear that the dynamics of the ACC are important. But this is far from trivial since eddy fluxes play a critical role in balancing the forcing of strong westerly winds that drive the ACC. The eddy fluxes transfer momentum downwards through form drag to depth where it can be diffused by mountain drag. An inherently nonlinear process involving baroclinic instability and large bottom topography. In this presentation, we examine the formation of AAIW which is a secondary effect to the ACC's nonlinear balance. Its formation is thought to be driven by air-sea surface fluxes of both heat and salt which produce cold and fresh waters to the south of the ACC. These waters move northward and then sink to form AAIW. Using some idealized models and theory, we examine many of the details in this process: the role of the turbulent mixed layer, the response of the interior flow to the surface forcing, the role of topography in inducing mixing and the role of convection.

NG12A-02 1045h INVITED

MESOSCALE MOTIONS IN THE UPPER OCEAN

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Mesoscale eddy transports of large-scale momentum and material tracers exert a profound influence on the oceanic general circulation, and on the exchange of heat, freshwater, and anthropogenic tracers between the ocean and the atmosphere. In present climate models, the ocean horizontal grid resolution is O(100) km or larger. At this resolution, the mesoscale dynamics are sub-grid scale and their effects must be parameterized. The mesoscale parameterizations used in ocean general circulation models (GCMs) typically represent the adiabatic release of potential energy by baroclinic instability in the interior, as suggested by Gent and McWilliams (1990). However, as the surface is approached, eddy fluxes develop a diabatic component, because density is maintained vertically homogeneous by strong mixing, while motions are constrained to be horizontal near the boundary. In this study we discuss the dynamical consequences of the transition to diabatic horizontal eddy fluxes in the upper ocean, and we propose closure schemes to account for this transition.

URL: <http://mit.edu/raffaele/www/>

NG12A-03 1100h

Numerical Simulations of Vortical and Wave Motion in Stably Stratified Turbulence

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Observations of the atmospheric mesoscale and oceanic submesoscale, where stable density stratification is strong but rotation is weak, have a certain universality: energy spectra, for instance, are often found to be relatively independent of location and season. Different theories have been proposed to account for these observations; however, the underlying physics remain controversial. This issue has implications for climate research, as the effects of these intermediate scales on the large-scale flow must be parameterized in GCMs. An important feature of these flows is that they can be decomposed into a potential vorticity-carrying (vortical) component and an internal wave component. In this talk, we examine some of the characteristics of these two modes of motion. Numerical simulations of an idealized stratified fluid are presented, in which large-scale vortical and wave motion are forced separately for a wide range of stratifications. In the vortical case, stratification leads to vertical decoupling and flat energy spectra in the vertical wavenumber  $k_z$ . The decoupling is shown to break down at a vertical scale of  $U/N$ , where  $U$  is the RMS velocity and  $N$  is the Brunt-Väisälä frequency; wave energy is generated by nonlinear interactions at this scale. We contrast these findings with wave-forced simulations, and discuss the relation of our numerical results with various asymptotic theories of wave and vortical mode dynamics.

NG12A-04 1115h

Low-Latitude Balanced Dynamics in Analyses and GCM Output

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A dynamical balance is derived, which is applicable in the equatorial middle atmosphere whenever zonal lengthscales significantly exceed meridional lengthscales. Although the traditional geostrophic relation formally breaks down at the equator, its meridional derivative remains valid, and is the natural balance that arises from the assumption of lengthscale separation. Anisotropy in the spatial scales as well as residuals associated with this balance relation are investigated in the context of output from the Canadian Middle Atmosphere Model and forecast analyses from the Met Office and the Canadian Meteorological Centre. In particular, it is shown that the residuals decrease with the zonal wavenumber, and that dynamical fields produced by the numerical model are more balanced than analyzed fields. Currently, forecast analyses exhibit more error in wind velocities in the tropics than at mid-latitudes. Consistent application of a balance relation in assimilation schemes should prove useful in improving future analyses.

URL: <http://www.atmosph.physics.utoronto.ca/people/matt/atmos-res.html>

NG12A-05 1130h

The Spatial and Temporal Structure of ENSO Nonlinearity

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The spatial structure of asymmetries in sea surface temperature (SST) and surface air temperature (SAT) between average El Niño and La Niña events is considered. It is demonstrated that in historical SST and SAT reconstructions, the anomaly spatial pattern that changes sign between El Niño and La Niña events (the "linear" signal) strongly resembles that of principal component analysis (PCA) mode 1, while that which does not change sign (the "nonlinear" signal) resembles the pattern of PCA mode 2. The linear and nonlinear patterns also strongly resemble the standard deviation and skewness fields, respectively. Furthermore, temporal subsampling of long (130-year) SST reconstructions suggests that the magnitude of the nonlinear signal and its similarity to PCA mode 2 are functions of the strength of ENSO, as measured by the standard deviation of the PCA mode 1 time series. Finally, it is found that several coupled general circulation models (GCMs) considered, the spatial and temporal structure of the El Niño/La Niña asymmetry is captured only by the GFDL R30 model, despite large biases in its covariance structure.

NG12A-06 1145h INVITED

An Oscillating Jet in the Cape Cod Bay

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During the spring months, the Cape Cod Bay is a roaming ground for the North Atlantic right whale, perhaps the most endangered whale species in the world. The whales are observed to travel along the topographic steps that run parallel to the shore, eating plankton patches that form in the coastal water. In this region, off the coast of Provincetown, there is an oscillatory current with the same period as that of the ambient tides. The location of the current and its periodicity suggest that the topography and tides play fundamental roles in generating the jet. This current, depending on its velocity profile, may become unstable and generate vortices. It is likely that the local surface convergences and divergences in the tidal flows and vortices are related to the aggregation of the copepods (*Calanus Finmarchicus*), which are the right whale's primary food source. Understanding the dynamics of

this jet is essential to predicting the spatial and temporal patterns of the copepods, which will in turn help us understand the likely locations and feeding history of the whales. In this talk we discuss results of the first phase of this study, that of the oscillatory jet in the Cape Cod Bay. This jet is rather complicated since it involves complex topography and coastlines, bottom and lateral friction, stratification and numerous other effects. Rather than study this system in fine detail, we investigate an idealized model that captures the essential features. In the context of this model, we first compute possible profiles for the oscillating jet. We then solve the linear stability problem to determine how the growth rates depend on the various parameters. Finally, and most importantly, we study the nonlinear problem to observe the time evolution of the instability process along with its equilibration. This provides some insight into how the instabilities are related to fluid transport across the shelf.

NG21A CC: 516 D Tuesday 0830h

Scaling and Fractals in the Earth, Atmosphere, and Hydrosphere: Resolution Dependence and Nonlinear Variability II

*Presiding: D Schertzer, Ecole Nationale des Ponts et Chausées; B Sapoval, Ecole Polytechnique*

NG21A-01 0830h

How Hawaiian lava flow Textures Rhyme with Anisotropic Scaling

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Textural morphology of subsurface lava flows is an expression of the intense stress applied at the surface during an eruption over a large range of scales. Pahoehoe and A'a Hawaiian textures are typical examples illustrating different conditions of volcanic eruption styles. However a particular and prominent aspect of these different textures is the ubiquity of scaling properties, implying a scaling symmetry over a wide range of scales. While the existence of a scaling and multi-scaling may reveal the continuity of a dynamic process over these scales it is also important to consider these properties in a more general context where the (scale by scale) differential anisotropy is taken into account. Indeed, a qualitative well known difference between the two Hawaiian texture types is the differentially oriented structures present in the Pahoehoe lavas as for example in the ropy type Pahoehoe. In such cases, generalized scale invariance (GSI) could provide new powerful insights for describing highly variable anisotropic phenomena. We will discuss this question through Pahoehoe and A'a textures acquired in Hawaii studying images spanning the range of millimeters to meters. In particular we may combine isotropic and anisotropic results to compare structures revealing stratification, rotation or both from more isotropic growing texture flows.

NG21A-02 0845h INVITED

Multifractal PMP Estimates in the Eastern US - Spatial Variability and Temporal Stability

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Multifractal analysis provides a framework to estimate physically meaningful estimates of the magnitude of extreme precipitation events, and to determine the risk associated with events of known magnitude. Specifically, the multifractal behavior of rainfall at daily (327 gauges) and monthly (1400 gauges) timescales, as well 6 - hourly fluxes of precipitable water from NCEP-NCAR Reanalysis was characterized. This study showed that multifractal estimates of the return periods of conventional PMP estimates (< 100,000 years) differ substantially from the desired values (about 1,000,000 years) in engineering design. Evaluation of this result for small dams in the Northern Appalachians implies that the reliability of existing structures is substantially lower (up to 100 per cent) than the assumed design standard. A detailed analysis of the

effects of climate variability and terrain focused on the spatial patterns of the codimensions of rainfall time-series (convex time scaling exponents) for all raingauge locations and precipitable water fluxes on the NCEP reanalysis grid over two time-periods: 1950 to 1970 and 1971 to 1997. Overall, the analysis resulted in consistent estimates of multifractal parameters over both time and space. Over short durations (1 to 30 days), the spatial variability exhibited by the codimensions is consistent with synoptic weather patterns. Daily codimensions along the Atlantic and Gulf coasts decreased over time, which coincided with increased coastal precipitation maxima in the second period. Elsewhere, the changes were not statistically significant, although it should be noticed that differences between the two periods at any location are larger than the spatial differences associated with orographic precipitation enhancement. Over longer durations (1 to 12 months), spatial variations in rainfall accumulations suggest an intensification of orographic enhancement effects (> 500 m elevations). The scaling behavior of precipitable water fluxes was similar to that of the raingauge data in that the spatial patterns of the co-dimensions at short time-scales reflect the predominant synoptic scale weather patterns, while at seasonal to interannual timescales the variability is controlled by regional orography. Building upon this study, a framework for risk assessment of the severity extreme events for climate impacts' studies at regional and global scales is presented. Douglas, E. and Barros, A.P., 2003: Probable Maximum Precipitation Estimation Using Multifractals: Application in the Eastern United States. *J. Hydrometeorology*, Vol. 4, No. 6, 1012-1024.

#### NG21A-03 0900h INVITED

##### Atmospheric Turbulence Structure and Precipitation Occurrence in a Tropical Climate

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Our work presents a connection between the estimated structure of turbulence in the lower atmospheric boundary layer and the probability of occurrence of a convective storm at the location of estimation, in a tropical climate. The same-day predictive capability of turbulent structure is being evaluated, given that during the rainy season, tropical storms develop in a matter of less than an hour, so a forecast lead time of only a few hours can therefore be useful. The evaluation procedure has been run on data collected in 1999 during the TRMM-LBA project at a site in Rondonia, Brazil, and the results have been found to be very encouraging.

#### NG21A-04 0915h

##### Modeling Hydrothermal Mineralization: Fractal or Multifractal Models?

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Hydrothermal mineralization occurs when the natural geo-processes involve the interaction of ore material-carrying hydrothermal fluids with rocks in the earth's crust in a specific geological environment. Mineralization can cause element concentration enrichment or depletion in the country rocks. Local enrichment may form ore body that can be mined for profit at the current economic and technological conditions. To understand the spatial distribution of element concentration enrichment or depletion caused by mineralization in a mineral district is essential for mineral exploration and mineral prediction. Grade-tonnage model and mineral deposits size distribution model are common models used for characterizing mineral deposits. This paper proposes a non-linear mineralization model on the basis of a modified classical igneous differentiation mineralization model to describe the generation of multifractal distribution of element concentration in the country rocks as well as grade-tonnage fractal/multifractal

distribution of ore deposits that have been often observed in hydrothermal mineralization. This work may also lead to a singularity model to explain the common properties of mineralization and mineralization-associated geochemical anomaly diversity and the generalized self-similarity of the anomalies. The model has been applied to a case study of mineral deposits prediction and mineral resource assessment in the Abitibi district, northern Ontario, Canada.

#### NG21A-05 0930h INVITED

##### Seveso 1986, Chernobyl 1976: a physicist' look at 2 ecological disasters

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Seveso suffered a chemical accident with a severe loss of superoxide material (TCCD) released in the atmosphere; Chernobyl was a world known nuclear accident. The pollution induced by the two accident are analysed in term of fractal models. The first case involved a limited micro ecological system; the second one spread over a macro ecological system. The pollution is reproduced by means of simple Fractal Sum of Pulses models in the Seveso region; for the Chernobyl accident in northern Italy and in several European Countries. The 2 accidents are also analysed in terms of Universal Multifractals showing that the parameters  $\alpha$  and  $C_1$  are those describing respectively rainfall (Seveso) and cloud formation (Chernobyl).

#### NG21A-06 0945h INVITED

##### El Niño Model Identification: Deterministic or Stochastic?

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There is an ongoing discussion about the dynamical properties of El Niño/Southern Oscillation (ENSO). According to one hypothesis ENSO can be fully described as a low dimensional chaotic process. A second hypothesis states that stochastic forcing has to be taken into account. Deciding for one hypothesis by fitting different model classes to observational data appears to be difficult: Conceptual models might all be rejected in statistical terms because of high discrepancies due to the too simple model structure. On the other hand too complex models lead to overfitting, inhibiting any significant selection due to the lack of data. We rather focus on another strategy for model identification by defining characteristics that have to be reproduced by a useful model. Recently the relation between amplitude and period of oscillations in conceptual ENSO models has been investigated. We suggest to choose this relation as a criterion for model identification. This way we present a detailed study for different ENSO models of intermediate complexity as well as for real data.

#### NG22A CC: 516 D Tuesday 1030h

##### Scaling and Fractals in the Earth, Atmosphere, and Hydrosphere: Resolution Dependence and Nonlinear Variability III

**Presiding: J Pomeroy**, University of Saskatchewan; **S Lovejoy**, McGill University

#### NG22A-01 1030h INVITED

##### Use of Radar Profilers as Tools for the Determination of Space-Time Variability of Precipitation

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For remote sensing of precipitation from radar and satellites to fulfill its ultimate potential it will be necessary to improve the precision of rain retrievals and to optimize the assimilation of the data into numerical models. It is well known from developments in data assimilation that for optimal performance models require information on the error covariance of the parameter being measured. In general, this means information is required on the measurement error of instruments as well as the representativeness of the measurements themselves. In the case of precipitation measurement it is necessary to develop more information on the variability of precipitation fields within precipitating cloud systems. This presentation considers approaches to the determination of space time variability of precipitating cloud systems using profilers and scanning radars.

#### NG22A-02 1045h INVITED

##### Multifractal prediction of hydrological extremes and the RIO research program

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One of the main research themes of the current RIO (Risque Inondation / Flood Risk) program of the Ministry of Environment in France is the prediction of extreme hydrological events and the development of new tools for their prediction, prevention and alert. Deterministic models based on various physical and/or statistical approaches are still not capable to capture the phenomena of extreme precipitation and floods. It is well known that one of the main difficulties for the description of hydro-meteorological extremes is the colossal variability of their intensities over a wide range of space-time scales. To contribute to the RIO program, our group uses the multifractal framework not only to explain the power-law fall-off of probability distributions for hydrological-meteorological extremes, but also to explore a link between the observed variability and the underlying physics. We analyze space-time distributions of precipitation and discharges over widely different hydrological regions. A multifractal data analysis performed in the space-time domain produces - amongst other results - a physically-based tool for the clear distinction and multifractal description of flash-floods. We illustrate these methods on two recent flooding events in France: the Abbeville phreatic floods in 2001 and the flash floods in Gard in 2002.

URL: <http://www.multifractal.jussieu.fr>

#### NG22A-03 1100h

##### Are snowcovers monofractal or multifractal?

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Previous research has identified the spatial variability of snowcovers as being fractal at very small scales, transitioning to random variability at scales larger than a fractal cutoff. The fractal component of the variability has been identified as the primary cause of the observed fractal geometry of partially ablated snowcovers, and as the primary source of the frequency distribution of snow water equivalent (SWE) in the original snowcover. To date, the simple monofractal model has been sufficient to explain observed snowcover behaviors for individual landscape units. Given the widespread evidence of multifractality in geophysical data sets, it was