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Analysis of temperature records in North Asia and North America shows that over the last 30 years the warming is as much 2°C/decade in winter. The ongoing changes in the regime of the pan-Arctic rivers due to global change are pronounced strongly in North Asia and North America both. We consider the long-range variability in the riverine discharge as an indicator of climate regional change that is coincident also with a long-range increase of the Siberian river-runoff of about 165 km³, permafrost warming, change in ice growth rates in the Arctic, decrease in the Arctic Sea ice extent, strengthening of the Arctic Oscillations and North Atlantic oscillations after 1970. Our study identifies changes in seasonal variability of the Siberian river discharges in the second half of the 20th century. In this report we are looking mostly for connection among atmosphere, runoff, and marine environment (including sea ice) in the poor explored East-Siberian region using historical datasets and our original field data (1995-2003). First time the long-term oceanographic data are compared with the bottom sediment isotope data that allows to study change in position of boundary between the Pacific derived waters and "local" shelf waters (diluted by the Lena and other rivers). In the past three decades mean values of annual discharge increased for Great Siberian rivers: Ob, Yenisey and Lena by 5.7%, 6% and 3%, respectively. Same time, the mean value of winter discharge has increased by 13% for the Ob, 45% for the Yenisey, and 25% for the Lena. The seasonal redistribution of the river discharge of the Yenisey, Ob, and Lena might be connected more or less with hydropower development (dams). Anyway, due to winter discharge total annual Siberian river input into the Arctic has increased by 4.5% during the 1970-2000 in comparison with the period 1945-1970. In the second half of the 20th century the Siberian rivers delivered 0.03 - 0.07 Sv (1 Sv=106m³/s) of freshwater into the Arctic Basin annually. This is comparable to the mean annual production of bottom water on the shelves surrounding the Canadian Basin (about 0.05 Sv), which enters the intermediate depth layer. On average in the cold season 0.01 Sv of riverine freshwater and 0.04 Sv in summer enter the Siberian shelf. Our evaluation shows that from 1970 to 1999 a mean river input (Ob, Yenisey, and Lena) to the Siberian shelves has increased of about 0.003-0.006 Sv. Discharge anomalies between the Lena, and Ob and Yenisey shows synchronous variability until the climate shift of early 1970s, when drastic increase of Great Siberian river's wintertime discharge was obtained. It agrees quantitatively with the cumulative ice production over the East-Siberian polynyas. The calculated correlation matrix between cumulative curves of ice-condition in the Siberian seas, the ice export through Fram Strait, and the Lena discharge shows the best correlation for time lag of 4, 5 and 6 years, because it is a sum of time needed for riverine water extension onto the shelf and time for ice export to the Fram Strait. A spectral analysis of annual mean discharge shows maxima with periods of 2 yr, 3-4 yr and 6-10 yr in all Siberian rivers that agrees well with periodicity in the Vangengeim' indices of atmospheric circulation.

H32A-04 1120h

Freshwater Runoff to the Barents Sea Under Present and Future Climate Conditions

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Climatic changes may have a large impact on hydrological processes in the Arctic and sub-Arctic. Global warming may lead to a shift in the snowmelt season and more evaporation in summer, although these changes might be counteracted by an increase in precipitation. Changes in the land surface hydrology will in turn affect the discharge regime of the rivers and the amount of freshwater entering the Arctic Ocean. However, in analysing the impact of climate change on arctic river discharge, previous studies have been complicated by the fact that climate models are not able to realistically simulate lateral fluxes of water, nor the water balance of large river systems. Hydrological models are therefore indispensable in analysing the sensitivity of Arctic hydrology to climate change, but face limited data availability and usually have to rely on empirical process descriptions. In the present study we use a regional climate model to drive a physically based hydrological model of major river basins in Northern Europe draining towards the Barents Sea. This approach leads to a realistic simulation of hydrological processes, including snowmelt and river discharge, and a correct representation of the water balance and the discharge regime of these arctic and sub-arctic rivers. The first results indicate a shift in the snowmelt runoff peak in spring of

about 20 days or more by the end of this century. However, the amount of discharge during peak flow remains more or less the same or shows only a slight increase. We also found a significant increase in the annual volume of freshwater runoff that, in some river basins, was proportionally larger than the projected increases in precipitation.

H32A-05 1135h

Lena River Water Propagation over the Eastern Part of the Laptev Sea Shelf

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The Lena River is one of the major sources of fresh water into the Siberian part of the Arctic Ocean. This study is focused on regularities of the Lena River waters propagation over the Laptev Sea shelf. Summer salinity (S), temperature (T) data and the Lena River runoff and temperature data are analyzed over the period 1965-2001. An integral approach of estimation salt and heat content of 5 m thickness layers was applied for several regions within the eastern Laptev Sea shelf. This part of the sea is under the permanent strong fluvial impact because 89 % of the Lena River waters come through eastern delta channels. The data analysis shows that cyclonic (CCR) and anticyclonic (ACCR) atmospheric circulation regimes essentially affect the propagation and redistribution of the Lena river runoff as well as different mechanisms of river and marine water interaction. There is a negative correlation between summer river runoff and surface layer salt content under CCR conditions implying that river discharge primarily controls the freshening of the surface water layer. Under CCR onshore winds prevent the northward propagation of the river plume. The river plume becomes thicker and stably stratified in comparison to ACCR conditions. It causes limited entrainment of ambient salty waters resulted in persistent negative correlation between river discharge and surface layer salt content. Under ACCR conditions the correlation between surface layer salt content and river discharge is positive. Offshore winds prevailing under ACCR result in considerable plume northward redistribution and weakening of the vertical density gradient. The positive correlation in this case suggests that the surface layer salt content under ACCR is strongly affected not only by the freshening due to riverine flux but also due to enhanced salinisation via the entrainment of the ambient salty waters. The heat content of surface layer is affected by both heat exchange with atmosphere and river heat flux. The study of heat fluxes is still under way.

H32B CC: 520 C Wednesday 1030h

Flow, Sediment Transport, and Stream Ecology I

Presiding: A Roy, Universit de Montral; S Lane, University of Leeds

H32B-01 1030h

Linking Sediment Transport to Coherent Flow Structures: First Results Using 2-Phase PIV and Considerations of the Origin of Large-Scale Turbulence

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The origin and scaling of large-scale coherent flow structures has been of central interest in furthering understanding of the nature of turbulent boundary layers, and recent work has shown the presence of large-scale turbulent flow structures that may extend through the whole flow depth. Such structures may dominate the

entrainment of bedload sediment and advection of fine sediment in suspension. However, we still know remarkably little of the interactions between the dynamics of coherent flow structures and sediment transport, and its implications for ecosystem dynamics. This paper will discuss the first results of two-phase particle imaging velocimetry (PIV) that has been used to visualize large-scale turbulent flow structures moving over a flat bed in a water channel, and the motion of sand particles within these flows. The talk will outline the methodology, involving the fluorescent tagging of sediment and its discrimination from the fluid phase, and show results that illustrate the key role of these large-scale structures in the transport of sediment. Additionally, the presence of these structures will be discussed in relation to the origin of vorticity within flat-bed boundary layers and recent models that envisage these large-scale motions as being linked to whole-flow field structures. Discussion will focus on if these recent models simply reflect the organization of turbulent boundary layer structure and vortex packets, some of which are amply visualised at the laminar-turbulent transition.

H32B-02 1045h

The Numerical Simulation of Time Dependent Flow Structures Over a Natural Gravel Surface.

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Research undertaken over the last few years has demonstrated the importance of the structure of gravel river beds for understanding the interaction between fluid flow and sediment transport processes. This includes the observation of periodic high-speed fluid wedges interconnected by low-speed flow regions. Our understanding of these flows has been enhanced significantly through a series of laboratory experiments and supported by field observations. However, the potential of high resolution three dimensional Computational Fluid Dynamics (CFD) modeling has yet to be fully developed. This is largely the result of the problems of designing numerically stable meshes for use with complex bed topographies and that Reynolds averaged turbulence schemes are applied. This paper develops two novel techniques for dealing with these issues. The first is the development and validation of a method for representing the complex surface topography of gravel-bed rivers in high resolution three-dimensional computational fluid dynamic models. This is based upon a porosity treatment with a regular structured grid and the application of a porosity modification to the mass conservation equation in which: fully blocked cells are assigned a porosity of zero; fully unblocked cells are assigned a porosity of one; and partly blocked cells are assigned a porosity between 0 and 1, according to the percentage of the cell volume that is blocked. The second is the application of Large Eddy Simulation (LES) which enables time dependent flow structures to be numerically predicted over the complex bed topographies. The regular structured grid with the embedded porosity algorithm maintains a constant grid cell size throughout the domain implying a constant filter scale for the LES simulation. This enables the prediction of coherent structures, repetitive quasi-cyclic large-scale turbulent motions, over the gravel surface which are of a similar magnitude and frequency to those previously observed in both flume and field studies. These structures are formed by topographic forcing within the domain and are scaled with the flow depth. Finally, this provides the numerical framework for the prediction of sediment transport within a time dependent framework. The turbulent motions make a significant contribution to the turbulent shear stress and the pressure fluctuations which significantly affect the forces acting on the bed and potentially control sediment motion.

H32B-03 1100h

Characterisation of 3D Hydrodynamic Flow Structures Associated With Instream Boulder and Pebble Clusters

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H32C CC: 520 A Wednesday 1030h

Advances in Understanding the Global Water Cycle II

Presiding: R Lawford, NOAA Office of Global Programs; **J Entin**, NASA Headquarters; **R Avissar**, Duke University

H32C-01 1030h

Revisiting ENSO

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This study analyzes monthly global hydroclimatology variables during a period from 1988 through 1999 from Reynolds's SST, NVAP, GPCP, and ERA-40 data sets. Common in time empirical orthogonal functions (EOF) analysis on the variables reveals the known pattern of ENSO. This study is able to show monthly spatial evolutions, prior and following ENSO events, of the analyzed variables including their common variations globally. This study lends a further insight into the ENSO events that is useful for their prediction.

H32C-02 1045h

Can We Isolate an ENSO Signal in Precipitation?

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There is growing consensus that space time variability of precipitation is changing in different parts of the globe. To assess the influence of anthropogenic changes on precipitation variability, it is important to first understand and quantify the characteristics of natural fluctuations in precipitation. Several authors have suggested that the natural variability we observe in the global climate system can be modeled as a collection of quasi-periodic oscillations varying on characteristic timescales superimposed onto a slowly varying red noise background. El Niño-Southern Oscillation (ENSO), the most globally active of such quasi-oscillatory processes, has been observed to be the dominant source of variability in global precipitation. Because ENSO contributes to precipitation variability in different parts of the world, identifying and isolating the contribution of ENSO to observed patterns of global precipitation variability is useful for predictability and climate change studies. We will present a method that combines the maximum overlapping discrete wavelet transform with principal component analysis to identify and isolate a global ENSO signal from monthly precipitation records. The proposed method is able to identify and isolate an ENSO signal in global precipitation that is strongly correlated with tropical SST anomalies and is consistent with previously described patterns of the ENSO teleconnection.

H32C-03 1100h

Using Combined Water Balance Computations for Estimating Changes in Terrestrial Water Storage of Major River Basins: Theory and Validation

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We investigated the three dimensional flow patterns and structures associated with instream boulder and pebble clusters. Adding boulders to streams is often used as a restoration strategy to provide fish shelter. Despite the success of such practices, the hydraulic effects of adding boulders are poorly understood. The study site was located on the Little Southwest Miramishi River, New Brunswick. Boulders were added in patches with dimensions of 3 m wide (cross stream) and 2 m long (downstream) located within 10 m from the bank. Detailed bed topography of the added patches and of control sections were surveyed using a Leica 800 series total station. We used an acoustic Doppler velocimeter (ADV) to measure high frequency (25 Hz) velocity signals in three-dimensions (3D) with the objectives of characterising the general flow characteristics and structures induced by the added boulders and the local turbulent structures shed from individual boulders. Detailed velocity profiles were also measured around naturally occurring pebble clusters within the study reach. We conducted digital camera visualisation experiments at specific locations to further investigate shedding structures. 3D turbulent characteristics were determined through autocorrelation and spectral analyses of individual velocity time series. We plotted detailed turbulent kinetic energy (TKE) profiles and distributions on patches and around individual boulders. Patches and individual boulders produced flow structures not observed in the upstream profiles. We observed localised macro-scale effects immediately downstream from patches and found that micro-structures around individual boulders are site specific, highly transient and intermittent. We observed sheltering and protrusion effects in both ADV measurements and visualisation experiments. This research shows that adding boulders considerably alters the local turbulent flow and the micro-scale habitat.

H32B-04 1115h

The Horseshoe Vortex in Gravel-Bed Rivers: Does It Exist?

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This paper presents evidence that questions field and laboratory observations that horseshoe vortices form around individual grains and groups of grains (i.e. pebble clusters) in gravel-bed rivers. The classical horseshoe vortex is driven by a junction vortex that forms immediately upstream of the particle or particle cluster. No study has yet to demonstrate that this junction vortex does indeed form in natural gravel-bed rivers. In this paper, we present a series of experiments based upon high resolution Particle Image Velocimetry (PIV) to explore how the junction vortex changes its character as we move from a smooth bed to a fully irregular gravel-bed, and from simple idealised objects to a complete pebble cluster. These experiments show that in situations where the bed is not smooth or where the object is not idealised, the junction vortex does not form. This is because of imbrication on the stoss side of imbricate pebble clusters which inhibits roll up of the boundary layer region and reduced momentum transfer to the bed on the stoss side of loose clusters due to complex particle shapes. However, we hypothesise that whilst the junction vortex (and the horseshoe vortex) do not appear to exist around formed pebble clusters, there are reasons to suggest that during cluster formation, a vortex may form. As the vortex forms, it invokes a series of feedback processes that lead to stabilisation of the cluster which in turn destroy the vortex.

H32B-05 1130h

Spatial heterogeneity of near-bed hydraulics above a water-lain gravel bed exposed to high Reynolds number flows

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Hydraulic conditions close to the boundary of gravel-bed rivers are of significant interest for understanding macroinvertebrate ecology. Here we report some of the hydraulic observations made as part of a wider experimental programme which is investigating the relations between macroinvertebrate movement behaviour, near-bed hydraulics and substrate sedimentology. Describing and quantifying near-bed flows above rough boundaries remains difficult because of the diverse shapes, sizes and configurations of surface particles, and the challenging task of measuring velocities above such surfaces at various flows. Quantifying near-bed hydraulics can be achieved by (1) describing the spatial heterogeneity of flow characteristics and (2) seeking generalised relations between distribution parameters and dimensionless measures of the flow and bed conditions. In this paper we describe the spatial heterogeneity of near-bed hydraulic characteristics above a water-lain gravel bed. A cast of a gravel-bed was placed in an experimental channel and exposed to three high Reynolds number flows. For a dense grid of 99 points, 3-D velocity measurements were made using an Acoustic Doppler Velocimeter at four elevations close to the bed. The data allow examination of the spatial heterogeneity of characteristics such as velocity direction and magnitude, turbulent kinetic energy and Reynolds stresses, and the search for functional relationships between key parameters. Here we report results that show how spatial heterogeneity varies with Reynolds number and height above the bed. We also explore some simple means of describing these relations.

H32B-06 1145h

Swimming in turbulent flow - profitable or costly ?

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Fish swimming performance has long been of interest to researchers. Experiments on swimming performance are generally performed under conditions which minimise flow heterogeneity. However, fish live in environments where intense fluctuations of flow velocity and pressure occur. Only recently, studies emerged that consider the effect of turbulence on the swimming performance of fish. Research has shown that fish may benefit from turbulence. For example, rainbow trout swimming behind an obstacle which produced stable vortex shedding, profited from the energy of these vortices. Fish adjusted their swimming patterns to slalom between the vortices which resulted in a reduction in muscle activity suggesting that fish reduced energy expenditure of swimming. Similarly, sockeye salmon exploited recirculation zones during upriver spawning migration to minimise energy expenditure. In contrast to these investigations showing that fish may actually profit from turbulence, several studies suggested that turbulence increases energy expenditure of swimming. Sustained swimming speed of fish decreased with increasing turbulence intensity suggesting an increase in swimming costs. Similarly, Atlantic salmon swimming in turbulent flow have 2- to 4-fold increased energy expenditure in comparison to estimates obtained under minimised flow heterogeneity. We will give an overview of recent studies and of new experimental evidence showing how turbulence affects fish behaviour, energetics and distribution and we discuss the relevant scales at which turbulent flow structures affect fish depending on its size. These results are from special interest not only for fisheries management, habitat restoration and biodiversity conservation but also for conceptualisation and construction of migratory fish pathways.