[3]Technical University of Hamburg, Technical University of Hamburg, Hamburg, Germany, Hamburg, Germany

Coastal sediment stability has been extensively studied through the measurement of the critical shear stress required to initiate particle erosion, using instruments such as the cohesive strength meter (CSM) and the Gust microcosm, among others. Such work has included analysis of the biogenic stabilisation potential arising from the growth of benthic algae, principally diatoms, as a biofilm on the sediment surface. The production of extracellular polymeric substances (EPS) by algae contributes to this stabilisation by forming a gel-like matrix at the sediment surface. Low-temperature scanning electron microscopy (LTSEM) has been used to visualise the microfabric of the sediment, in particular the binding of sediment particles by the EPS.

This present study extends this work by investigating the nature of the eroded particles using in-line laser holography. A ruby red laser was passed through a microcosm erosion chamber in which artificial and natural sediments were eroded. A three-dimensional holographic image of the particle field above the sediment was recorded in which eroded particles could be examined independently or as part of the erosion field. Initial work used a variety of sediments (sand, glass beads, mud) with different concentrations of added EPS and demonstrated the importance of EPS in determining the tertiary structure of the eroded floc material. In addition, the influence of natural biofilms grown in situ was also investigated. Data presented will include analysis of the fine scale structure of the sediments using LTSEM linked to critical stress conditions and the eroded material. This combined approach of LTSEM and holography under controlled stress conditions gives new information on the mechanisms of biogenic stabilisation by polymer secretions. Initial holographic studies have shown good resolution for discrimination between EPS, sediment particles and diatom cells, and shown the erosion process using particle field holography for the first time.

OS11G-92 0830h POSTER

Evidence for Widespread Mixing-Induced Convective Sedimentation from Surface Plumes

Wayne W McCool[1] (1-206-543-6454; wmccool@ocean.washington.edu)

Jeffrey D Parsons[1] (1-206-221-6627; parsons@ocean.washington.edu)

[1]University of Washington, School of Oceanography Box 357940, Seattle, WA 98195, United States

Water from a flooding river intruding into the ocean typically results in a surface layer of sediment-rich water over a saline ambient fluid. One mechanism by which the sediment from these hypopycnal plumes can fall through the stratified and stable water column is convective sedimentation (CS). CS can take many forms, but refers to the effective removal of material without allowing it to separate from the surrounding fluid. Preliminary experiments of CS using natural sediment in a quiescent settling tank were performed to measure the subtle signatures (temperature, salinity, and sediment concentration) of CS processes. These experiments aid in the characterization of the diverse physics that can impact CS, and they help guide future modeling efforts. In addition, we have constructed a new experimental facility, which uses a race-track flume to produce a steady flow of sediment laden freshwater above a saltwater basin. A series of experiments with natural sediment from the Eel River were conducted in this facility to accurately simulate the turbulence structure of a highly-concentrated river mouth. These experiments were performed such that the viscous dissipation rate is reflective of natural river plumes. We have established that CS will occur at riverine sediment concentrations commonly found on many river margins (400-600 mg/L). The results of these experiments show that convection is dependent on sediment concentration, water-column stratification, and dissipation rate. Application of these results show that CS can be found on most small mountainous river systems and that the flux of sediment due to CS can be at least as strong as flocculation-enhanced settling.

OS11G-93 0830h POSTER

Seasonal Deposition of Sediment Near the Mouth of the Po River

Cindy Palinkas[1] ((206) 543-8544; cpalinkas@ocean.washington.edu); Charles Nittrouer[1] ((206) 221-6607; nittroue@ocean.washington.edu); Robert Wheatcroft[2]; Leonardo Langone[3]; Stefano Miserocchi[3]; Andrea Ogston[1]; Annika Fain[1]

[1]University of Washington, School of Oceanography, Seattle, WA 98105

[2]Oregon State University, College of Ocean and Atmospheric Sciences, Corvallis, OR 97331

[3]Istituto Geologia Marina-CNR, via P. Gobetti 101, Bologna 40129, Italy

In October 2000, a 100-year flood of the Po River occurred. ^{7}Be, a short-lived radioisotope (half-life 53.3 days), was used to examine the thickness of the flood deposit during a cruise in December 2000. The deposit was found to have thicknesses up to 15 centimeters and was located immediately adjacent to the distributary channels at the river mouth. Without knowing the source function for ^{7}Be discharge, ^{7}Be thicknesses might be minimum estimates for true thicknesses of the flood deposit. The location of the deposit is linked to the low-energy conditions present in the Adriatic Sea at the time of flood sedimentation. The flood signature was identified in x-radiography (physical stratification), ^{7}Be (uniform activities), and grain size (high clay percent). The Po deposit differs significantly from deposits observed after floods of the Eel River (northern California). A major difference between the flood deposits is the location (at the Po River mouth; seaward and downstream of the Eel River mouth), which highlights the distinct difference in energy conditions of the Adriatic Sea and the North Pacific Ocean.

Subsequent cruises in June 2001 and October 2001 have followed the fate of the Po flood layer, and have examined changes occurring during the winter/spring and the summer months, respectively. These studies have found depositional layers exhibiting different trends than those observed in December 2000. The causes of these differences could be related to varying influences of the deltaic distributaries and to subsequent transport and mixing of sediment. The significance of these seasonal variations for the longer-term sediment-accumulation pattern near the Po River can be observed (e.g., through use of ^{210}Pb geochronology; half-life 22.3 years) along the sediment dispersal path southward.

OS11G-94 0830h POSTER

Pattern of Sediment Distribution in Setentrional Coast of Rio Grande do Norte State, Northeastern Brazil

Helenice Vital[1] (55.84.215.3831; helenice@geologia.ufrn.br); Venerando Eustaquio Amaro[1] (55.84.215.3831; amaro@geologia.ufrn.br); Werner Farkatt Tabosa[1] (55.84.215.3831; farkatt@yahoo.com.br); Ingred Guimaraes Guedes[1] (55.84.215.3831; imgguedes@yahoo.com.br); Karl Stattegger[2] (kstattegger@gpi.uni-kiel.de); Luciano Henrique Caldas[2] (lc@gpi.uni-kiel.de)

[1]Pos-Graduacao em Geodinamica e Geofisica - Universidade Federal do Rio Grande do Norte - ANP/PRH22, Caixa Postal 1596 Campus Universitario Lagoa Nova, Natal, RN 59072-970, Brazil

[2]GPI - Christian Albrecht Universita, Olshausenstrasse, 40, Kiel 24118, Germany

Systematic mapping of the Setentrional Coast of Rio Grande do Norte State, northeastern Brazil, between Sao Bento do Norte and Macau cities, reveals the pattern of sediment distribution on this area. This domain belongs to a larger complex in PETROBRAS oil exploration research. The study area configuration was strongly affected by a Mesozoic-Cenozoic vertical tectonism. Geologically, the area is part of the Potiguar Basin. The terrestrial portion of the basin has a trough limited by NE-SW faults. The offshore portion of the basin is limited by E-W and NW-SE faults that form the boundaries of a homocline dipping towards the ocean. The graben and horst structures present on the Potiguar Basin played an important role on the shelf morphology and sedimentation. A sediment distribution chart for this area was obtained on basis of interpretation of remote sensing images, seismic profiles (side scan sonar, ecobathymeter and Boomer), as well as surface sediment sampling on the shelf and vibracore on the shoreline. Analysis of this data set shows that the oceanographic and geomorphological features as well as the coastal evolution and tectonic setting of the northeastern coast of Rio Grande do Norte State may explain the distributional pattern of sediment found around this coastal zone. Sand dune fields, lagunes, mangroves and sand spits characterize the shoreline. A minimum of four beachrock lines are found both on the shoreline and on the inner shelf. Seawards a belt of siliciclastic sands are found nearshore along the longshore drift followed by a complex of mixed carbonatic-siliciclastic medium grained sands at intermediated zone while bioclastic gravel are found most after 10 m water depth. The biogenic content is mainly represented by corallinea algae (Melobesya and Halimeda) and benthonic foraminifera although we can found ostracode, gastropode and bivalves in minor amounts. Quartz is the principal component in the terrigenous sediments with heavy minerals as accessory. Mud sediments are restrict to areas near estuaries and on river canyons. Side scan sonar records reveals a seabed covered by well-developed sandwaves of different scales, showing the efficiency of longshore drift. Boomer records show the existence of paleo-channels cutting the Galinhos spit, confirming ancient system of island barrier developing for the current spit.

OS11H HC: 316 B Monday 0830h

The North Atlantic Ocean and Its Changing Climate I Climate

Presiding: **B Dickson,** CFEAS, The Laboratory**; T M Joyce,** Woods Hole Oceanographic Institution

MON

OS11H-01 0830h INVITED

Exploring the Role of the Atlantic Thermohaline Circulation in Rapid Climate Change

Jochem Marotzke (44-23-80-593755; Jochem.Marotzke@soc.soton.ac.uk)

School of Ocean and Earth Science, Southampton Oceanography Centre, Southampton SO14 3ZH, United Kingdom

Ocean-atmosphere interactions in the North Atlantic are responsible for heat transports that keep northwestern Europe 5-10°C warmer than it would otherwise be. This is caused by the ocean's thermohaline circulation (THC), driven by temperature and salinity differences. However, existing THC patterns might not continue: climate models suggest that the increasing atmospheric greenhouse-gas burden could dramatically weaken the THC and associated circulation systems within a few decades. Furthermore, palaeo-data indicate large and rapid variability in North Atlantic THC strength during the past 20,000 years, and recent observations on the extent and thickness of Arctic sea-ice show that a new regime shift may already be underway. The UK has recently decided to fund a large observation-based programme to investigate the dynamics and sensitivity of the North Atlantic THC, and the climatic consequences of potential rapid changes. It will focus on delivering: (i) the establishment of efficient and cost-effective systems for detecting and quantifying THC change; (ii) the identification of the main northern high-latitude drivers of the THC; (iii) an improved fundamental understanding of interactions of THC dynamics with the atmosphere and cryosphere; (iv) quantitative palaeo-estimates of past THC changes and their climatic consequences; (v) advances in conceptual understanding of the THC. I will outline the major elements of the programme as they have been defined to date.

Next, I will present the dynamical ideas behind, and current planning work toward, efforts to observe the Atlantic THC on a continuous basis. Such monitoring will be a prerequisite for the ultimate goal of predicting THC variability. In particular, I will discuss the possibility that a continuous observing system could be based on density time series over the whole water column, at the western and eastern boundaries. These measurements would be combined with monitoring of the boundary current transport, bottom pressure variations near the margins, and wind and altimetric information along the section combining the endpoints. I will present design studies of such observing systems based on the output of numerical models.

URL: http://www.nerc.ac.uk/funding/thematics/rcc/

OS11H-02 0845h

Trends in Arctic Ocean Freshwater and Heat Content Over Decadal and Seasonal Time Scales, 1950-1989

Inna Shapiro[1] (907-474-1963; inna@iarc.uaf.edu)

Jia Wang[1] (907-474-2685; jwang@iarc.uaf.edu)

Roger Colony[1] (907-474-5115; rcolony@iarc.uaf.edu)

Moto Ikeda[2] (011-706-2360; mikeda@eoas.hokudai.ac.jp)

[1]Frontier Research System for Global Change, International Arctic Research Center, University of Alaska Fairbanks, 930 Koyukuk Drive, PO Box 757335, Fairbanks, AK 99775-7335, United States

[2]Graduate School of Environmental Earth Science, Hokkaido University, North27, East3, 1-28-53, Higashi-ku, Sapporo 065, Japan

Variations of Arctic Ocean freshwater and heat content were examined from 1950 to 1989 to provide both a historical reference and first-order estimate of trends for the two Arctic Ocean climate variables. Over the latitude interval 65° N to 90° N, gridded fields of Arctic Ocean salinity, temperature and density from the surface to depths of 4 km were extracted at 50 x 50 km horizontal resolution from the Environmental Working Group (EWG) Atlas for the study period.

Using data from four decades (1950 - 1959, 1960 - 1969, 1970 - 1979 and 1980 - 1989) and two seasons

(summer and winter), the mean freshwater reservoir and heat content were computed. The spatial anomalies of freshwater reservoir indicate a basin-scale variability at decadal to inter-decadal timescales. However, the spatial anomalies in heat content show greatest variability in the Greenland, Iceland and Norwegian (GIN) Seas, and the Nansen Basin over decadal timescales. In the GIN Seas, the alternate positive and negative anomalies in heat content over the study period suggest atmosphere - ocean interaction in the region.

OS11H-03 0900h

Variability of intermediate and deep water renewal in the Greenland Sea during the 1990s

Johannes Karstensen[1,2] (+49 431 600 4213; jkarstensen@ifm.uni-kiel.de)

Peter Schlosser[1] (+1 845 365 814; peters@ldeo.columbia.edu)

Douglas Wallace[2] (+49 431 600 4200; dwallace@ifm.uni-kiel.de)

John Bullister[3] (+1 206 526 6741; johnb@pmel.noaa.gov)

Johann Blindheim[4] (+47 5 238569; johan.blindheim@imr.no)

[1]L-DEO of Columbia University , 61 Rt 9W, Palisades, NY 10964, United States

[2]Institut für Meereskunde , Düsternbrooker Weg 20, Kiel 24105, Germany

[3]NOAA/PMEL, 7600 Sand Point Way, Seattle, WA 98115, United States

[4]Institut for Marine Research, PO Box 1870, Bergen 5024, Norway

From hydrographic and transient tracer (CFC 11, CFC 12, tritium/^{3}He) time series from 1991 to 2000 ventilation and its response to mean surface forcing variability is studied in the Greenland Sea and its connection with the other two gyres, the Norwegian and Iceland Seas.

The ventilation of intermediate depths (down to 1600 m) in the central Greenland Sea gyre appears to be triggered by atmospheric forcing, while ice seemed to play no role during the time period under consideration. The so-formed Greenland Sea Arctic Intermediate Water (GSAIW) is warmer and less salty compared to characteristics at the end of the 1980s. This is probably due to the warming over the region during recent years. The winters of 1994/95 and 1999/2000 were both marked by large increases in tracer inventories as well as strong heat losses and virtually no ice coverage. Formation rates of GSAIW estimated from changes in the tracer inventories during these two winters were about 0.5 Sv and close to zero in other winters, thus an average formation rate for the 1990's of 0.1 Sv is found. Subduction of newly formed water should be caused by baroclinic eddies and is of the order of 200 to 400 m y^{-1}, as derived from vertical age tracer gradients.

The temperature and salinity of deep waters further increased during the late 1990s at a rate of 0.01 Ky^{-1} and 0.001 y^{-1}, respectively. Transient tracer concentrations remained practically constant over this time suggesting a continued balance between the inflow of warm, salty, and tracer depleted Arctic Ocean Deep Water, and diapycnal mixing with no direct renewal from the surface.

The spreading of newly formed water is studied using isopycnal mapping of tracer ages and by qualitatively describing the spreading of the 'youngest' water. We observed that deep, as well as intermediate, water flows from the Greenland Sea towards the Iceland Sea.

OS11H-04 0915h

A Freshwater Jet on the East Greenland Shelf

Sheldon Bacon[1] (+44-23-8059-6441; S.Bacon@soc.soton.ac.uk)

Gilles Reverdin[2]

Ignatius G. Rigor[3]

Helen M. Snaith[1]

[1]Southampton Oceanography Centre, Empress Dock, Southampton SO14 3ZH, United Kingdom

[2]Laboratoire d'Oceanographie Dynamique et de Climatologie, 4, place Jussieu, Paris Cedex 05 75252, France

[3]Applied Physics Laboratory, University of Washington 1013 NE 40th Street, Seattle, WA 98105, United States

In August 1997, RRS Discovery cruise 230 (WOCE A25) ran a hydrographic section in to Cape Farewell on the southern tip of Greenland. The closest approach to the shore was 2 nm in a water depth of 160 m, over the east Greenland shelf. Analysis of the hydrographic data (CTD, vessel-mounted acoustic Doppler current profiler, thermosalinograph) has revealed a current flowing south-westwards, about 15 km wide, 100 m deep and centred about 10 km offshore. We believe it to be driven by meltwater runoff from Greenland. This feature, which we call the East Greenland Coastal Current (EGCC) carries a little less than 1 Sv (10^6 m^3/s) with peak current speeds of ∼1 m/s at the surface. The centre of the EGCC lies on a salinity front with maximum salinity contrast ∼4 psu between coast and shelf break, and between surface and bottom. A spot value of freshwater transport is 0.06 Sv (1800 km^3/yr), which is equivalent to ∼30 % of the Arctic freshwater gain. The presence of the EGCC and its continuity up the east Greenland coast as far as Denmark Strait is confirmed in satellite SST images and surface drifter tracks. We estimate the sensitivity of its freshwater flux to changes in melt season mean surface air temperature to be >25 % per 1 °C.

OS11H-05 0930h

A Longlived Deep Convective Eddy in the Greenland Sea

Jürgen Holfort[1] (49-40-42838-2997; holfort@ifm.uni-hamburg.de)

Jan Backhaus[1] (backhaus@ifm.uni-hamburg.de)

Detlef Quadfasel[2] (dq@gfy.ku.dk)

Peter Wadhams[3] (pw11@cam.ac.uk)

[1]Institut für Meereskunde, Universität Hamburg, Troplowitzstr.7, Hamburg 22529, Germany

[2]Niels Bohr Institute for Astronomy, Physics and Geophysics, Juliane Maries Vej 30, Copenhagen, Denmark

[3]Scott Polar Research Institute, Lensfield Road, Cambridge, United Kingdom

Very deep convection in the Greenland Sea ceased after 1971 and winter time convection in the 1990's normally reached only to a maximum depth of 1200 to 1500m. On a RV Jan Mayen cruise in March 2001 a convective eddy reaching depths of 2400m was found at approximatly 75°N, 0°W with a diameter of about 10nm.

Small scale surveys of this eddy were made again in April and September 2001 and are planned for February 2002. A profiling float was deployed in this eddy and stayed in it at least until November 2001. For all this time the eddy stayed at approximatly the same geographic position. Looking at historical data, an eddy or signs of it can be found also in previous years at almost the same position, e.g. in 1997 to a depth of about 1900m.

URL: http://www.ifm.uni-hamburg.de/∼holfort/OS.html

OS11H-06 0945h

Circulation of Atlantic Water in the Northern North Atlantic and Nordic Seas.

Kjell Arild Orvik[1] (47-55582602; orvik@gfi.uib.no)

Peter P. Niiler[2] (619 534 4100; pniiler@ucsd.edu)

[1]Geophysical Institute, University of Bergen, Allegaten 70, Bergen N-5007, Norway

[2]Scripps Institution of Oceanography, 9500 Gilman Drive, La Jolla, CA 92093-0213, United States

Major pathways of near-surface Atlantic water in the northern North Atlantic and the Nordic Seas are presented using 999 near-surface Lagrangian drifters and hydrography. Based on the drifter data in the northern North Atlantic, the inflow of Atlantic water to the Nordic Seas over the Scotland-Greenland ridge and the establishment of the two-branch Norwegian Atlantic Current are discussed. This two-branch current appears to have a topographic trapped eastern branch and a western branch as a frontal jet, also topographically guided. The origin of the drifters that pass through the Svinøy section which cuts through the Atlantic inflow just to the north of the Faroe-Shetland channel, is presented. Downstream from the Svinøy section, the eastern branch is stable and extends to the Arctic. The western branch follows the western slope of the Vøring Plateau toward Jan Mayen where it turns northeastward along the eastern slope of the Mohn Ridge. Farther northward toward the Fram Strait the drifters and hydrography still reveal the maintenance of a two-branch Norwegian Atlantic Current

OS11H-07 1020h

Circulation in the Nordic Seas and Contribution to the Scotland-Færoe-Iceland-Greenland Ridge System Overflow from Five Years Observation of a Tracer Release in the Greenland Sea

Marie Jose Messias[1] (44 1603 593 763; m-j.messias@uea.ac.uk); Andrew J. Watson[1] (44 1603 593 761; a.j.watson@uea.ac.uk); Anders Olsson[2] (andols@amc.chalmers.se); Jean Claude Gascard[3] (33 1 44 27 70 70; gascard@lodyc.jussieu.fr); Kevin Oliver[1] (44 1603 593 395; k.i.oliver@uea.ac.uk); Truls Johannessen[4] (4755589804; truls.johannessen@gfi.uib.no); Jon Olafsson[5] (3545520240; jon@hafro.is)

[1]School of Environmental Sciences, University of East Anglia, Norwich NR4 7TJ, United Kingdom

[2]Deptment of Anal. and Marine Chemistry, University of Göteborg, Göteborg S41296, Sweden

[3]Laboratoire D Oceanographie Dynamique et de Climatogie, Universite Pierre et Marie Curie, Paris 75005, France

[4]Geophysical Institut, University of Bergen, University of Bergen, Bergen N-5007, Norway

[5]Marine Research Institute of Reykjavik, Marine Research Institute of Reykjavik, Reykjavik 121, Iceland

The Nordic Seas serve as one of the principal conduit of the meridional overturning of the oceans (MOC). It comprises the Greenland Sea, the Iceland Sea and the Norwegian Sea. Warm salty Atlantic water entering the Nordic Seas is transformed by heat loss to the atmosphere into dense water that will subsequently overflow the Scotland-Færoe-Iceland-Greenland Ridge system and produce North Atlantic Deep Water (NADW). In 1996, a unique tracer experiment was begun to study the northernmost limb of the MOC. A patch of sulphur hexafluoride (SF6) was released on an isopycnal surface near 300 m depth in order to tag the waters of the central Greenland Sea, long since considered as an important contributor to the NADW. Here, we present the dispersion of the tracer, examining mixing rates in the Greenland Sea and the pathway of the tagged water over the Nordic Seas and the overflows from 1996 to 2001.

OS11H-08 1035h

The East Greenland Current System: Sources, Recipes and Pathways

Jens Meincke[3] (49-40-42838-5985; meincke@ifm.uni-hamburg.de)

Bert Rudels[1] (358-9-613-94-428; bert.rudels@fimr.fi)

Eberhard Fahrbach[2] (49-471-4831-1820; efahrbach@awi-bremerhaven.de)

Gereon Budéus[2] (49-471-4831-1702; gbudeus@awi-bremerhaven.de)

Patrick Eriksson[1] (358-9-613-94-433; patrick.eriksson.@fimr.fi)

[1]Finnish Institute of Marine Research, PL 33, Helsinki FIN-00931, Finland

[2]Alfred-Wegener-Institut für Polar- und Meeresforschung, Postfach 120161, Bremerhaven D-27515, Germany

[3]Institut für Meereskunde der Universität Hamburg, Troplowitzstrasse 7, Hamburg D-22529, Germany

The East Greenland Current (EGC) is the main conduit for the waters returning from the Arctic Ocean and the Nordic Seas to the North Atlantic. In addition to low salinity Polar Surface Water (PSW) and sea ice the EGC transports deeper lying waters exiting the Arctic Ocean, and Atlantic Water recirculating in Fram Strait (RAW). These water masses are already in Fram Strait dense enough to contribute to the dense Denmark Strait Overflow Water (DSOW). On its route along the Greenland slope the EGC exchanges waters with, and becomes augmented by intermediate water masses form the Greenland and Iceland Seas. In 1998 RV Polarstern and RV Valdivia occupied several hydrographic sections on the Greenland continental slope from Fram Strait to south of Denmark Strait, crossing the EGC. The Arctic Ocean waters and the RAW could be followed to just north of Denmark Strait, where the EGC encounters the northward flowing branch of the Irminger Current. Strong mixing then occurs both within the EGC itself, and between the waters of the two currents. Arctic Intermediate Water from the Iceland Sea (IAIW) was not clearly observed in Denmark Strait, but part of the temperature reduction of the warm core of the EGC just north of the strait may be caused by mixing with the colder IAIW. The overflow plume was stratified and Θ-S properties of the overflow

water were within the triangle defined by the upstream thermocline and temperature maximum waters and the colder deep waters of the EGC. Entrainment of ambient water is thus not required for explaining the evolution of the characteristics of the overflow plume at the first part of its decent. Less saline overflow water was observed on the upper part of the slope and identified as Polar Intermediate Water (PIW). The PIW properties were similar to those of the thermocline present in EGC already in Fram Strait, and it is conceivable that the PIW source is the upper (Θ>0) part of the thermocline in the Arctic Ocean.

OS11H-09 1050h

Interannual Variations in Wintertime Mixed Layer Depth, Inorganic Carbon and Nutrients in the Irminger and Iceland Seas

Jon Olafsson[1] ("354-552-0240"; jon@hafro.is)

Solveig R. Olafsdottir ("354-552-0240"; solveig@hafro.is)

[1]University of Iceland and Marine Research Institute, Skulagata 4, Reykjavik IS 121, Iceland

The Irminger and Iceland Seas undergo strong seasonal variations. Relatively warm and saline Atlantic Water prevails west of Iceland in the Irminger Sea but northeast of Iceland in the Iceland Sea, Arctic Water usually predominates but but some Polar Water influence in the surface layers is common. Convective mixing is induced in both regions in winter by winds and heat loss to the atmosphere. The nutrient concentrations in the surface layer that result from the winter vertical mixing processes may vary interannually. The nutrients from vertical mixing and those carried by eddy diffusion into the euphotic zone have strong influence on the regional scope for new production and uptake of CO2 from the atmosphere.

The winter mixed layer depth is found to be variable in the Irminger and Iceland Seas, but it reaches much deeper in the Irminger Sea as a halocline limits the vertical convection in the Iceland Sea. The ranges of the related variations in salinity, density and nutrient concentrations are similar in both regions but the nutrient variations are proportionately greater in the Iceland Sea. The Iceland Sea surface stays undersaturated with respect to carbon dioxide throughout the year whereas the Irminger Sea may become supersaturated in winter on account of vertical mixing. Statistical relationships between mixed layer depth and surface water properties are examined and the effects of interannual variations in advection.

OS11H-10 1105h

The role of convection and seasonal to interannual variability on carbon uptake in the Nordic seas

Truls Johannessen[1] (-4755584327; truls@gfi.uib.no); Leif Gunnar Anderson[3]; Richard Bellerby[1]; Marie-José Messias[2]; Are Olsen[1]; Anders Olsson[3]; Abdirahman Omar[1]; Ingunn Skjelvan[1]; Andrew Watson[2]

[1]Geophysical Institute, University of Bergen, Allegt. 70, Bergen 5007, Norway

[2]University of East Anglia, NR 4 7TJ, Norwich, United Kingdom

[3]Göteborg University Department of Analytical and Marine Chemistry, S-412 96 Göteborg, Göteborg, Sweden

Johannessen, T., Anderson, L.G., Bellerby, R.J.J., Messias, M.J., Olsen, A., Olsson, A., Omar, A.M., Skjelvan, I. and Watson, A.

During the EU projects ESOP and TRACTOR new information is obtained regarding the air/sea exchange of CO2 in temperate to polar region. The Greenland Sea is believed to be one of the most important areas on the globe in production of deep water. One of the main issues is to understand whether the thermohaline circulation is stable in its present mode of operation. Despite many years of extensive research, only a crude and qualitative understanding is at hand today, and many fundamental questions related to the basic nature of convective overturning in high latitudes are not resolved: what are the mechanisms, what are the driving forces, what are the quantities and ventilation rates, and what are the quantities of the associated fluxes of carbon? Specifically, we will focus on the carbon cycle the way it express itself during an intensive study of the Greenland/Nordic Seas. The general antropogenic CO2 uptake seems to follow the global uptake of 2 mmol/kg carbon pr. year. The physical carbon pump is stronger in the Greenland Sea than in other regions due to the low temperature in the surface water and the high wind speeds. During the summer a very low fCO2 as low as 200 matm are recorded. In the late spring/early summer a very low fCO2 exist in the surface waters and d13C seems to be decoupled from nutrient. We call upon partial thermal equilibration with the atmosphere to explain the pattern we observe in the Greenland Sea.

OS11H-11 1120h

What Causes the Recent Freshwater Storage and Export Anomaly in the Arctic Ocean?

Xiangdong Zhang[1] (1-907-474-2675; xdz@iarc.uaf.edu)

Moto Ikeda[2] (mikeda@ees.hokudai.ac.jp)

[1]Frontier Research System for Climate Change, International Arctic Research Center, University of Alaska Fairbanks, 930 Koyukuk Dr., Fairbanks, AK 99775, United States

[2]Graduate School of Environmental Earth Science, Hokkaido University, Sapporo, Japan

In recent ten years, the Arctic atmosphere, sea-ice and ocean changes significantly. The positive phase of Arctic Oscillation or North Atlantic Oscillation persists, causing anomalous atmospheric low pressure and cyclonic circulation over the Arctic Ocean and accompanying the amplification of anthropogenic effects with anomalous higher air temperature extending to the Arctic Ocean from the Eurasian continent. All of these changes may affect freshwater storage in the Arctic Ocean and freshwater export from the Arctic Ocean to the North Atlantic, which may influence the North Atlantic Thermohaline Circulation. We employed a coupled Arctic ocean/sea-ice model and carried out simulations forced by the climate monthly mean and monthly anomaly corresponding to the leading mode of sea level pressure, which is derived from NCEP/NCAR reanalysis data. Results show that the overall freshwater storage are decreased by about 2% between the positive and negative phases of the leading mode. The recent phase shift of atmospheric leading mode gives rise to the piling up of liquid freshwater in the Beaufort Sea and the Canada Basin off the Canadian Archipelago. Correspondingly, the liquid freshwater export through Fram Strait in the upper ocean layer increases by 12.2%.

OS11I HC: 318 A Monday 0830h

Viruses and Prokaryotes in Aquatic Systems I

Presiding: **C Brussaard,** Netherlands Institute for Sea Research**; C Suttle,** Univ. of British Columbia**; R Goericke,** Scripps Institution of Oceangraphy Integrative Oceanography**; H Grossart,** Grossart, H.-P.

OS11I-01 0830h INVITED

Assessing Viral Diversity in the Sea

Grieg F Steward[1] (gsteward@cats.ucsc.edu)

Chris M Preston[2] (preston@mbari.org)

Ed F DeLong[2] (delong@mbari.org)

[1]UCSC, Ocean Sciences Dept, Santa Cruz, CA 95062, United States

[2]MBARI, 7700 Sandholdt Rd, Moss Landing, CA 95039, United States

Viruses are believed to be the smallest and most numerous form of life in the oceans and many other aquatic environments. As ubiquitous and obligate intracellular parasites, viruses are persistently and intimately commingling with the genetic material of their hosts. Knowledge of the information content of viral genomes as well as how this information is transmitted and expressed is thus essential if we are to fully understand the physiology, ecology, and evolution of complex plankton communities.

One challenge when analyzing natural viral communities can be obtaining sufficient material of adequate purity. This is especially difficult for deep ocean where viral concentrations can be low. To facilitate collection from such environments, we developed an in situ ultrafiltration system which concentrates bacteria and viruses from 1000 liters of seawater in about 5 hours. The concentrates are useful for studying physical and genetic diversity of natural viral assemblages. We have recently constructed a shotgun library from marine viral DNA that is providing a glimpse of some of the natural genetic diversity of viruses the ocean. With shotgun libraries of very diverse mixed communities it is exceedingly difficult to piece together individual clones into larger contiguous fragments. Two means to improve the information content are to clone larger pieces or to reduce the sample complexity before library construction. In a complementary study related to the latter strategy, we have used the physical variations of viruses as means to fractionate complex assemblages. Pulsed field gel electrophoresis (PFGE) can resolve about 35 to 40 distinct viral genome sizes in a single sample. To further improve resolution we have used multi-dimensional fractionation. In this case, intact viruses are first fractionated based on combinations of size, mass, or surface charge characteristics prior to separation of their genomes. The results indicate that viral diversity in seawater can be grossly underestimated by single-dimension separation using only PFGE. Multi-dimensional fractionation of intact viruses should prove useful for library construction targeting specific groups of viruses. This approach will help establish links between genetic and morphological diversity and is a further step towards culture-independent approaches in viral ecology.

OS11I-02 0845h

Genomic analysis of an uncultured marine viral community

Mya Breitbart[1] (619-594-1336; mya@sunstroke.sdsu.edu)

Anca Segall[1] (asegall@sunstroke.sdsu.edu)

David Mead[2] (dmead@microgen.org)

Farooq Azam[3] (fazam@ucsd.edu)

Forest Rohwer[1] (frohwer@sunstroke.sdsu.edu)

[1]San Diego State University, Department of Biology. 5500 Campanile Drive, San Diego, CA 92115, United States

[2]Lucigen Corporation, 2120 W. Greenview Drive, Middleton, WI 53562, United States

[3]Scripps Institution of Oceanography, Marine Biology Research Division. 8750 Biological Grade, La Jolla, CA 92093, United States

The worlds oceans contain up to 10 billion viruses per liter, making them the most common biological entities by an order of magnitude. Marine viruses, the majority of which are bacteriophage, have enormous influences on global biogeochemical cycles and are major conduits of genetic exchange. Despite their importance, virtually nothing is known about the diversity of marine viruses or their evolutionary relationships to non-marine viruses. Here we report the first culture-independent analysis of a marine viral community using a genomics approach. Over 70% of the sequences obtained in this analysis were not significantly homologous to previously reported sequences in GenBank. The majority of the significant hits from the uncultured phage library encode genes from phage (32%) and mobile elements within bacterial genomes (30%). Genes from all major families of dsDNA tailed phage, as well as some representatives of algal viruses, were found among the significant hits to previously reported sequences. In addition, we observed sequences related to groups that have never before been reported in the marine environment, such as coliphage lambda. Of the sequences with significant homologies to phage, an overwhelming proportion (44%) were most closely related to the Podoviridae. These hits were almost evenly distributed between marine (Roseophage SIO1) and non-marine (coliphage T7, coliphage T3, and Yersinia pestis phiYe03-12) phage. In contrast, GenBank is biased towards the Siphoviridae, which only comprise a small fraction of our phage hits. Even the Myoviridae, the phage family least represented in GenBank, was more highly represented (20%) in the uncultured library than the Siphoviridae (14%). Therefore, it appears that the Siphoviridae may not be as common in the marine environment as the other groups of dsDNA tailed phage. In addition, we also observed a number of contigs within the library, demonstrating that viral diversity within the near-shore sample was relatively low, and that it is possible to shotgun sequence uncultured organisms from total communities.

OS11I-03 0900h INVITED

Marine Viromics: A Genomic Analysis of Vibriophage 16

Anca Segall[1] (619-594-4490; asegall@sunstroke.sdsu.edu)

Victor Seguritan[1] (619-594-4490; seguritan@yahoo.com)

Forest Rohwer[2] (858-534-3196; forest@ucsd.edu)

I. W. Feng[1] (619-594-4490; Ifeng@yahoo.com)

John H. Paul[3] (727-553-1168; jpaul@seas.marine.usf.edu)

[1]San Diego State University, 5500 Campanile Drive, San Diego, CA 92182, United States

[2]Scripps Institute of Oceanography, 8750 Biological Grade, San Diego, CA 92037, United States

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