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AWIPEV-INVEST 2005 - Sedimentological Investigations at the Coastal Interface in Shallow Kolhamnlaguna, Kongsfjorden, Western Svalbard

Background Information

The initial starting point for the AWIPEV-INVEST 2005 expedition (September 12-22) to Ny Ålesund has been the French-German AWIPEV fusion-workshop held at the European Science Foundation (ESF) in Strasbourg, France, on March 2 and 3, 2005. The main target of this workshop was to strengthen the French-German scientific collaboration on the joint research stations 'Koldewey' (AWI, Germany) as well as 'Rabot' and 'Corbel' (both IPEV, France) located at Ny Ålesund, Kongsfjorden, Spitsbergen (Fig. 1, Fig. 2). The expedition was designed as a pilot study for further joint research between IPÖ (Kiel), AWIPEV (AWI Bremerhaven, AWI Potsdam, IPEV Brest), M2C (University of Rouen), and the University of Besançon (ThéMA-CNRS) in the next 3-6 years.

The scope of the close future collaboration is to develop and pursue interdisciplinary project efforts in order to investigate the highly dynamic and climatically sensitive Arctic coastal interface influenced by various terrestrial, marine, biological and cryological factors.

Introduction and area of investigation

The global environmental and climatic importance of the North Polar Region has been realized since many years and will be focus of further studies (Brass 2002). Particularly, coastal and shallow marine dynamics in Arctic ecosystems like Kongsfjorden, influenced by various climatic and anthropogenic impacts as well as terrestrial and marine processes (e.g. coastal erosion, terrestrial sediment supply, habitat changes of marine life, tides and waves, sea ice), are of increasing importance and interest in terms of local, regional and global aspects of coastal development and ecology.

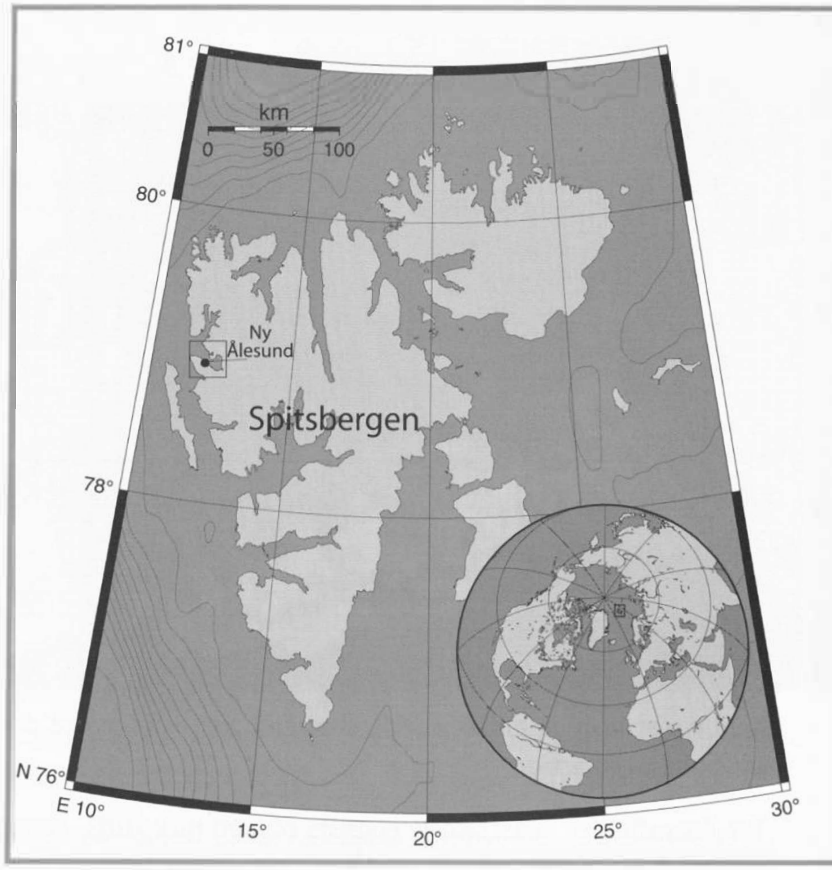

Figure 1 *Map displaying Kongsfjorden (see box around Ny Ålesund).*

Kongsfjorden (Fig. 2) represents one of the best year-round-accessible high latitude sites for research on Arctic-related bio-sedimentological processes at the terrestrial-marine interface. The German-French AWIPEV stations 'Koldewey', 'Rabot' and 'Corbel' located at Ny Ålesund provide optimum conditions for supporting international and interdisciplinary research programs.

Kongsfjorden is a 25km long and 5-10km wide, W-E extended, shallow meso-tidal bay at the NW coast of the Svalbard archipelago. The fjord is covered by ice during winter, and is generally ice free during summer (Mehlum 1991, Svendsen et al. 2002). Freeze-up (first frazil ice formation; thin level ice floes in coastal embayments and lagoons) starts in fall, while a rigid fast ice canopy or a closed drift ice cover, respectively, mostly does not develop before the end of the year or in early January (Gerland et al. 2004). Break-up of the ice cover varies interannually, and ice retreat generally starts between April and July.

The tidal range in the inner Kongsfjorden is to as much as 2.0m (Wangensteen et al. 2003; www.met.no). Current speeds and tidal flow velocities are in the range of about 8-10cm/s (Svendsen et al. 2002). The fjord is mainly influenced by Atlantic water masses with salinities of ~34. During summer, the fjord water masses are strongly and stable stratified subsequent to a surface layer of freshened water released from glaciers, iceberg melt and precipitation-induced terrestrial discharge (Svendsen et al. 2002). In spring, fall and early winter the

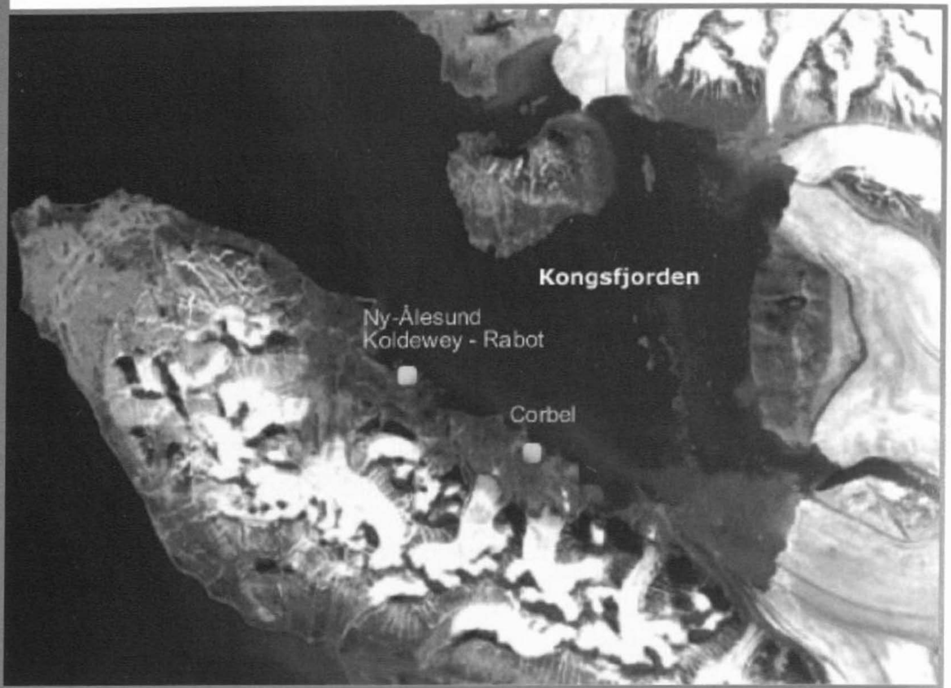

Figure 2 *Summer satellite image of Kongsfjorden (adapted from www.ifremer.fr). AWIPEV research stations are indicated. White and grayish terrestrial areas represent glaciers, while greenish marine zones indicate glacier and river particle plumes*

fjord water body is rather weakly stratified and more mixed due to increasing wind and wave action.

The Kongsfjorden coast widely consists of hard rock cliffs, permafrost soils and alluvial fan deposits as well as tidally influenced lagoons and lowlands (Héquette 1987). Hard rock, sand, and mud dominate the beach and surf zone, the littoral zone and the shallow shelf. Most of the terrestrial fine-grained material released to the fjord, however, is deposited in the inner part of the basin (Svendsen et al. 2002). Concentrations of suspended particulate material (SPM) during summer range from 20-30mg/l and show strong seasonality with lower values during winter.

Due to the influence of both Atlantic and Arctic water masses, a wide range of habitats occurs in the Kongsfjorden ecosystem. Marine benthic macroalgae - one of the principal current and future research foci in the Kongsfjorden - mainly grow on littoral hard ground and serve as sensitive ecological indicator in the tidally influenced littoral environment (Hansen & Haugen 1989, Bischof et al. 2002, Wiencke et al. 2004). Drifting sea ice and icebergs may have strong abrasive effects on local algae stocks. Additional physiological stress on algae may potentially result from summer and early fall sedimentary deposits delivered by terrestrial discharge and potential iceberg particle release.

The marine-terrestrial ecosystem of the Kongsfjorden coast consists of various individual sedimentological-biological-geochemical environments and habitats: (i) cliff or permafrost coast, (ii) alluvial fans, tidal lowlands and beach deposits, (iii) surf zone, littoral zone and shallow shelf surface, (iv) water column, and (v) sea ice. Since the environments and habitats mentioned are interlocked through various physical, biological, geological, sedimentological, hydrodynamic and geochemical processes, the individual parts of the ecosystem cannot be considered independently and isolated from each other.

Subsequent to a changing physical interplay of littoral fluvial, erosive, depositional, hydrodynamic and sea ice processes, we may expect various geo-bio-hydrological feedback mechanisms in the Kongsfjord coastal environment like e.g. changes in sediment deposition centers, increase of erosion, and changes of small scale hydrodynamics with subsequent potential impact on macroalgae habitat quality, shift of habitats, reduction of species and populations strengths, decrease/change of reproduction rates, and algae physiology. During the current period of global warming, these environmental feedback-mechanisms and changes may lead to a dramatic change or even damage of parts of the modern local Kongsfjorden coastal ecosystem.

Purpose of the expedition

The overall scope and purpose of the expedition was to improve our understanding of sedimentary, hydrodynamic and biological (macroalgae) processes and interactions in the Kongsfjorden littoral ecosystem, and particularly in and around the shallow Kolhamnlaguna northwest of Ny Ålesund (Fig. 3, Fig. 4).

We investigated Kolhamnlaguna under biological, sedimentological, cryological, and hydrodynamic aspects in order to learn more about the ecological network of environmental mechanisms (erosion, fluvio-glacial transport, deposition, littoral macroalgae ecology, tidal hydrodynamics, sediment dynamics, sea ice formation, sea ice sediment entrainment and transport) and geo-biological feedback mechanisms (e.g. sedimentological and geo-cryological influence on algae habitats, coastal changes etc.). Furthermore, we expect prognostic statements on future changes of the coastal ecosystem of Kongsfjorden, which might be indicative for other Arctic coastal environments. In order to reach this future goal, all data and scientific results gained will be provided to the broad Arctic research community.

Figure 3 *View to Kolhamnlaguna W of Ny Ålesund.*

The main scopes of our research program were:

- Identification and understanding of physical and biological interactions between individual near-coastal sedimentological-biological-cryological environments and habitats like (i) fluvial deposits, (ii) shore face and shelf bottom (littoral), (iii) water column and (iv) sea ice

- Particularly investigating interactions between coastal deposition and erosion, potential sea ice sediment entrainment, tidal dynamics, and finally biological processes of the Arctic coastal system (deposition of fluvial material and reworking of deposits, coupling of sedimentological and biological processes, feedback on benthic macroalgae)
- Conducting tank experiments on small scale hydrodynamics, particle transport and interactions between benthic macroalgae, fine grained sediment coverage and newly forming ice

Current and future research

During summer and fall, benthic macroalgae in shallow coastal waters of Kongsfjorden are partly covered by a layer of fine-grained rock particles most probably delivered by summer terrestrial discharge. The sediment cover may considerably influence or even reduce algae vitality and growth. The main topic of the AWIPEV 2005 expedition was to learn more about potential sedimentological and biological interactions at the terrestrial-marine interface and in the littoral zone of the Kongsfjorden ecosystem close to Ny Ålesund. The main scope of the fieldwork was to improve our understanding of the ecosystem-connection between (i) fluvial terrestrial transport, (ii) coastal and near shore deposition, (iii) local impact on macroalgae, (iv) hydrodynamic re-suspension and (v) turbulent sea ice entrainment of fine-grained particulate material.

Specific Current Scientific Questions

- Does the macroalgae sediment coverage exclusively consist of terrestrial rock particles or can we identify marine (microbiological) components?
- Can we trace pathways of terrestrial particles from river over near shore deposits (bottom sediments, macroalgae particle coverage) to potentially newly formed sea ice? Will terrestrial particles deposited in the littoral zone during summer be incorporated into newly forming sea ice in the following fall?
- Do turbulent hydrodynamic processes like Langmuir circulation (Lc; see chapter 2.2 for more detail) promote the cleaning of algae from the sediment coverage, the re-suspension of bottom sediments, and finally the entrainment of ice sediments?
- Can we distinguish between proposed 'macroalgae cleaning mechanisms' such as Lc and e.g. bottom currents, tides and wave action? Which is the steering hydrodynamic process to clean the macroalgae from the sediment coverage?

- Does turbulent new ice formation contribute to algae cleaning and to the erosion and removal of fine-grained bottom deposits thereby potentially increasing processes of coastal erosion?

Specific Future Scientific Questions

Outgoing from the preliminary results of the AWIPEV-INVEST 2005 expedition, we plan - and already partly conducted - further fieldwork in 2006 and 2007. Few of the future research goals consist in:

- Identifying terrestrial sources of littoral Kongsfjorden sedimentary deposits
- Further identifying particle pathways from terrestrial sources over temporal littoral deposition (bottom, macroalgae stocks) toward the entrainment into sea ice
- Investigating and identifying hydrodynamic processes (including turbulent new ice formation) in the littoral sedimentary regime of Kongsfjorden
- Investigating the physical influence (damage vs protection) of particle deposition on algae (physical suppression, reduction of incoming solar radiation) and the physiological response (photosynthesis, metabolism, habitat reduction and dislocation etc.) of algae on local sedimentary and glacio-sedimentary processes
- Identification of physiological algae damages and biological changes in littoral algae habitats subsequent to terrestrial sediment input; may water turbidity due to suspended particle matter (SPM; terrestrial discharge and/or re-suspension) shift the lower distribution limit of local macroalgae stocks?
- Simulating natural geo-biological coastal interface conditions in outdoor tank experiments
- Balancing sedimentary budgets of selected terrestrial/littoral interface sites in Kongsfjorden
- Conducting a winter experiment on sub-ice and polynia conditions as well as on related coastal geo-biological processes
- Relating our results to terrestrial discharge monitoring data (French Loven Flows and ALTUS-sediment-altimeter deployment projects)
- Satellite/digital photo-supported investigation of sedimentological-cryological processes (distribution and littoral deposition of fluvial particle plumes, formation of turbid sea ice, coastal morphodynamics etc.) on Kongsfjorden coast.

Methods and Material

In order to achieve the above current scientific and technical aims, we collected water, sediment and ice samples in and around the shallow Kolhamnlaguna in the inner Kongsfjorden (Fig. 4). In particular, we i) studied suspended particle and bottom sediment compositions in the Bayelva river delta and the adjacent bay (Kolhamnlaguna, Brandalpynten, Thiisbukta), ii) investigated the composition of particulate material on complete macroalgae and algae fragments, and iii) identified, quantified and qualified the entrainment of bottom material into locally formed new ice.

Additionally, we deployed an ADCP (Acoustic Doppler Current Profiler) in Kolhamnlaguna in order to monitor tidal currents and Lc rolls in the shallow water column, and we conducted outdoor non-freezing and freezing tank experiments on Lc-induced bottom sediment motion, dye flow, sediment-macroalgae-interactions, and ice-sediment entrainment.

Sampling, material and field measurements

Sample material was collected at 10 sites along the coast of Thiisbukta, Kolhamnlaguna, and Brandalpynten northwest of Ny Ålesund (Fig. 4; Table I, see Annex). Stations 1, 2, 3, and 4 were situated in - or close to - the Bayelva river delta. Stations 5, 6 and 9 were located off Brandalpynten, station 7 in a small Bayelva river lagoon, station 8 (a+b) in Kolhamnlaguna, and station 10 in Thiisbukta. The sampling sites were accessed by walking and by zodiac.

Delta sediments

Surface deposits from the subaerially exposed Bayelva river delta were sampled using a small plastic spoon. One sample (depth interval: 0-5 mm) was each obtained at sites 1 and 2 (Fig. 4; Table II, see Annex). At site 4, delta bottom sediments were sampled by hand in extremely shallow water (~10 cm) using a 100 ml syringe with tube-extension. The sediments obtained were filled in plastic beakers and stored under laboratory conditions for container transport.

Suspended particulate material (SPM)

A total of 14 SPM samples was collected at stations 3, 4, 5, and 6 either by hand (1 l PE-bottle, #3+4) or by Niskin bottle, and in sediment traps (#5+6; Fig. 5).

The trap samples were collected at Brandalpynten (Fig. 4) in ~13m deep water at 1m, 5m, and 10m above ground. The trap chain was deployed for periods of about 24 hrs over nearly two fully tidal cycles. The traps were fixed on a rope, which was moored at the bottom by a 40kg metal weight. Buoyancy providing fishery buoys maintained the trap chain in a vertical position.

The Niskin samples were each taken in 1m, 5m, and 10m water depth, and, thus, above the level of the proper sediment trap in order to collect material

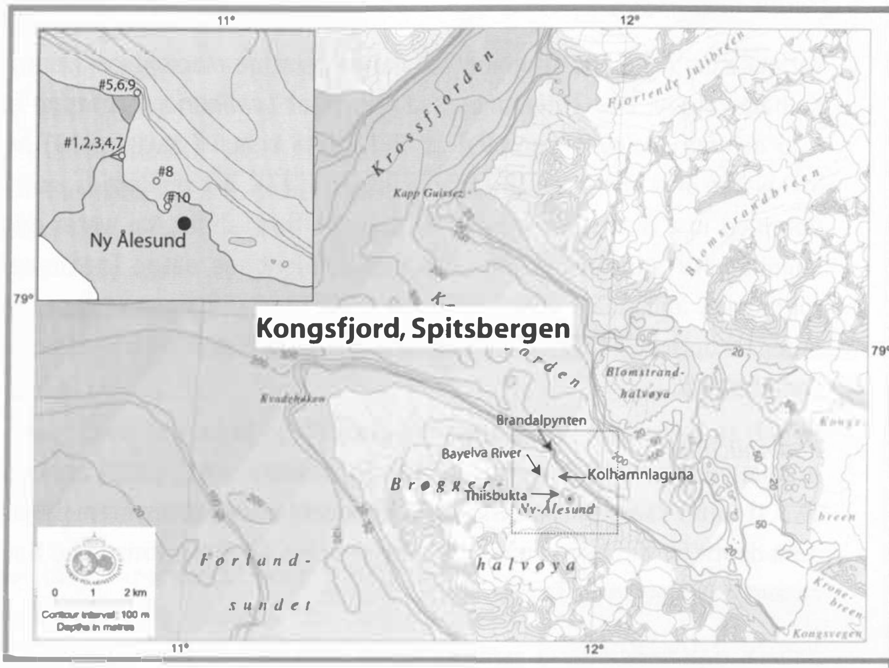

Figure 4 *Map displaying Kongsfjord (source of basic map: Norwegian Polar Institute; Hop et al. 2002, ftp://npolar.no/Out/ anne/ KongsfjordenGIS/web/index. html). Kolham-laguna, Brandalpynten, Bayelva River, and Thiisbukta are indicated. The small upper left inlet magnified from the stipple-line frame around Ny Ålesund shows the sampling locations.*

compositions potentially settling in the traps. Both the Niskin samples and the trap particles were filtered using pre-weighed, mixed-ester membrane filters with 0.45 µm pore diameter.

Fjord bottom sediments

Shelf surface deposits in shallow water (site 3) were obtained by hand using a 100ml syringe with tube-extension. Bottom sediment at deep locations (5, 8a) was sampled by diver support using 500ml Kautex bottles. A total of 3 surface sediment samples was obtained and stored for container transport and further sedimentological investigations.

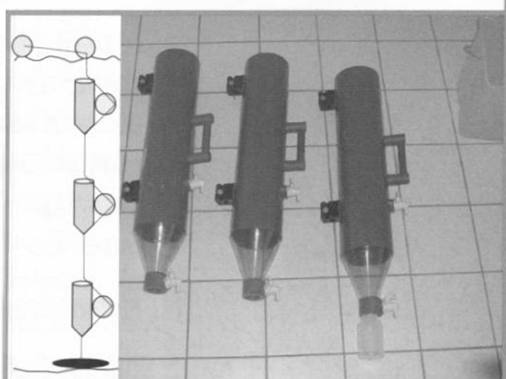

Figure 5 *Sediment traps for SPM collection (see vertical trap chain left).*

Lagoon ice and ice sediments

Floating ice floes were sampled at station 7 in a small, temporary tidal lagoon in the Bayelva River delta. The floes were cut into slices and melted in plastic containers in the laboratory, protected by a plastic folio against atmospheric particle pollution. Particulate matter was filtered from the melt water using pre-weighed, mixed-ester membrane filters with 0.45µm pore diameter. The filtered material was dried and stored for further sedimentological investigations (smear slides, binocular).

Marine macroalgae

Various complete and fragmented marine benthic macroalgae were sampled in Kolhamnlaguna and Thiisbukta. Fragments of *Laminaria saccharina* and *Saccorhiza dermatodea* were sampled at Thiisbukta beach (station #10) and in shallow water of a river mouth lagoon (station #7). A complete *L. saccharina* was obtained in a plastic sack by diver support from about 6m water depth in Kolhamnlaguna (station #8) together with ambient sea water. The algae were photographed, and smear slides were prepared from the algae surface sediments in order to optically (microscope) investigate grain size distribution and particle composition.

Radionuclides

Two 1l water samples were obtained by divers at Brandalpynten (#9) in ~9m and 13m depth for detection of I-129. The samples were alkalinized by NaOH in order to avoid oxidation of Iodide toward Iodine.

Salinity and temperature measurements

Water salinity and temperature were routinely determined in Niskin and trap samples using a portable conducto-meter.

Figure 6 *ADCP mounted on a heavy concrete bucket (with attached algae after overnight deployment).*

Acoustic Doppler Current Profiler (ADCP)

A 2MHz Nortek ADCP (Fig. 6) was deployed over a period of about 20 hrs in Kolhamnlaguna close to Thiisbukta in about 5m water depth in order to record near coastal currents over a fully tidal cycle, and to detect potential hydrodynamic indications for wind-wave-induced Lc.

Meteorology

During the expedition, 2m and 10m altitude data of wind velocity and direction, temperature and humidity were routinely recorded and provided by the AWI.

Tank experiments on Langmuir circulation (Lc) and macroalgae

Langmuir circulation (Fig. 7) consists of wind-wave induced, paired and counter rotating helical vortex pairs transporting momentum down into the water column thus having great impact on shallow water mixing (Langmuir 1938; Scott et al. 1969; Weller et al. 1985), sediment transport (Sutcliff et al. 1971; Gargett et al. 2004), and particle entrainment into newly forming ice (Dethleff 2005; Kempema & Dethleff 2006, Dethleff & Kempema 2007). Floating particles, like e.g. frazil crystals or seaweed, are collected in surface rows in Lc convergent zones. Tank studies in controlled laboratory conditions point to the origin of Lc by the superimposition of wind-wave induced surface stress and the longitudinal primary flow (resulting from the circulation consisting of the surface downwind flow and the bottom return flow deflected at the downwind wall of the tank (Fig. 7)), finally initiating the so-called secondary flow, or helical Lc (Mizuno & Cheng 1992; Mizuno et al. 1998; Uzaki & Matsunga 2000). The diameter of one Lc vortex in tank experiments is directly controlled by water depth (Dethleff & Kempema 2007).

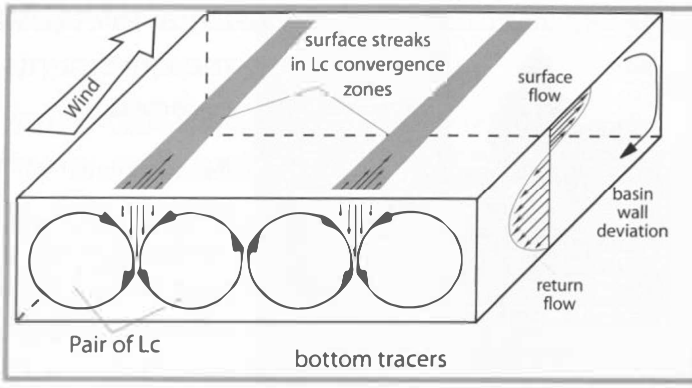

Figure 7 *Sketch of theoretic Lc development in tank experiments.*

Four outdoor tank experiments were conducted close to the ancient pier in Ny Ålesund. The tank measured 1.8m long, 0.8m wide and 0.18m deep (Fig. 8). The basin was filled with seawater of varying depths (exp. #1 and #2: 15cm; exp. #3: 11cm; exp. #4: 16cm) and exposed to natural local ambient atmospheric conditions (wind, temperature).

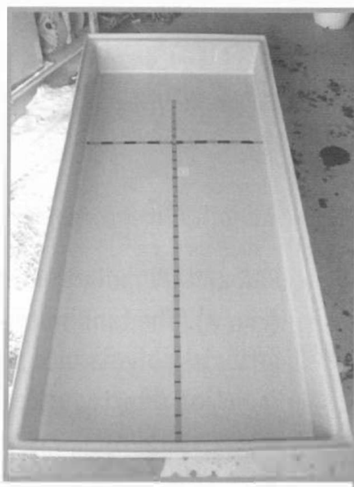

Figure 8 *Outdoor experiment tank with long- and cross-axis 5cm scale.*

In experiments #1 and #2, sediment originating from the Bayelva River delta was placed inline cross-wind on the tank bottom. Ice formed overnight, which was sampled and treated like the lagoon ice sample from the river delta. In experiment #3, we seeded the basin bottom with granular and dissolved potassium permanganate ($KMnO_4$) in a line perpendicular to the wind, and also in wind direction. In experiment #4, we fixed two cross-tank bottom-lines of juvenile *L. saccharina* rinsed and haltered in clean sea water before, and partly covered the algae with sediment from the Bayelva mouth for four days. Ice formed during the last night of the experiment #4 run. All experiment runs and observations were documented with a digital photo- and video-camera.

The target of the experiments was to generate wind-wave induced Lc under semi-controlled tank conditions. Lc formation was traced from tank bottom sediment patterns, and from $KMnO_4$ trajectories in the water column. We compared the tank results to observations of Lc formation in the fjord during fieldwork period, and to results of indoor freezing laboratory experiments (Dethleff & Kempema 2007).

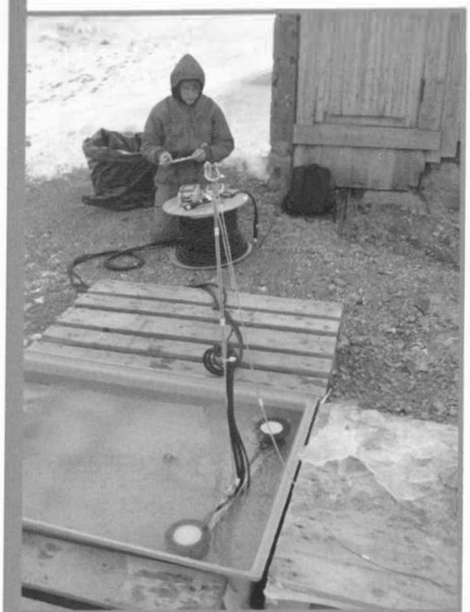

Figure 9 *UV radiation measurements in the experiment tank. Sensor detection unit is in the foreground (tank), data logging equipment triggered by a scientist is in the background.*

Ultraviolet (UV) radiation tank measurements

Equipment

Measurements of 'photosynthetically active radiation' (PAR; 400-700 nm spectrum) were conducted in the algae-sediment tank experiment #4 by a cosine corrected, flat-head underwater quantum sensor (LI-192SA, LI-COR) connected to a LI-1000 data logger (LI-COR Lincoln, USA; Fig. 9).

Underwater UVA and UVB radiation were both measured by a PMA2100 Radiometer (Solar Light Co. Inc., USA) equipped with two cosine corrected, flat-head underwater sensors in a water protected cylindrical box. The spectral response of the PMA2110 UVA detector covers the 320 to 400nm range. The PMA2106 UVB detector measures the UVB radiation in the range of 280 to 320 nm.

Radiation measurements

PAR and UV radiation were measured in the water column of the experiment tank (Fig. 9). The tank water was covered by a 0.8 to 1.5cm thick ice layer. We cut an artificial polynia into the tank ice in order to measure irradiance of PAR and UV radiation directly under the thin ice cover, and in the adjacent open tank water, where the sensor was situated ~1-2.5 cm under the surface. The measurements were conducted to investigate the potential influence of thin sea-ice on the attenuation of ambient PAR and UV radiation.

Laboratory methods

Sedimentology

Bottom deposits, SPM, sea-ice sediments, and the sediment layer on the algae surfaces were prepared for smear slide analyses in order to estimate the quantitative and qualitative sample composition under the binocular microscope.

Further laboratory investigations will include:

- Wet sieving and Atterberg separation of coarse, silt and clay fractions of shelf surface deposits, trap material, and ice incorporated sediments
- Qualitative and quantitative grain size and component analyses of bulk fraction
- Qualitative and quantitative component analyses of coarse fraction

- Grainsize analysis of sediment samples (LaserGranulometer, SediGraph, Coultercounter)
- Granulometric silt analysis (LaserGranulometer, SediGraph, Coultercounter) of bottom deposits, ice sediments, and trap material
- Qualitative and quantitative component analyses of silt fraction under the Scanning Electron Microscope (SEM)
- X-ray diffractometry of clay fraction

Radionuclide determination

The Kongsfjorden water samples obtained for radionuclide measurements will be analyzed for the extremely long-live species of I-129. European re-processing plants at Sellafield (GB) and La Hague (F) are generally regarded as the main sources for this radionuclide. The analysis will be carried out using an Acceleration Mass Spectrometer (AMS) at the ETH Zurich (CH) after sample preparation at the Center for Radio Protection and Radioecology (ZSR), Hannover (G). Sample collection and further treatment of the specimen is running partly under the guidance of Hartmut Nies (Bundesamt für Seeschifffahrt und Hydrographie, Hamburg).

Preliminary Results and Discussion

Bayelva River discharge – Source of local littoral deposits?

The Bayelva river discharges into the shallow, tidally influenced Kolhamnlaguna (Fig. 4, Fig. 10). The fall particle load of the river water close to the mouth (station #4) was 1.37 mgl^{-1} and was composed of 80% silt and clay (Table II, see Annex). Sand was reduced due to low discharge rates and current velocities. The river bottom at station #4 was also composed of fine grained clastic particles, whereas the river bottom few hundred meters upstream (stations #1 and #2) was composed of partly more sandy material.

The Bay water close to the shore at station #3 contained 4.76 mgl^{-1} particle load. The suspended particulate material was dominated by silt and clay; the bottom material at the same location was dominated by sand.

Preliminary estimates of qualitative particle composition reveal that the river bottom, the shore face and the suspended material in both environments are dominated by 80-95% of terrestrial material like mostly quartz particles with reddish iron oxide or zircon coatings and inclusions (quasi-ubiquitous material). From our preliminary results we can state that the sedimentological regime of the entire Bayelva river mouth and the adjacent inner Kolhamnlaguna is strongly influence by terrestrial debris flow, though the bay environment is also tide-controlled with ranges of as much as 2m during spring tide periods.

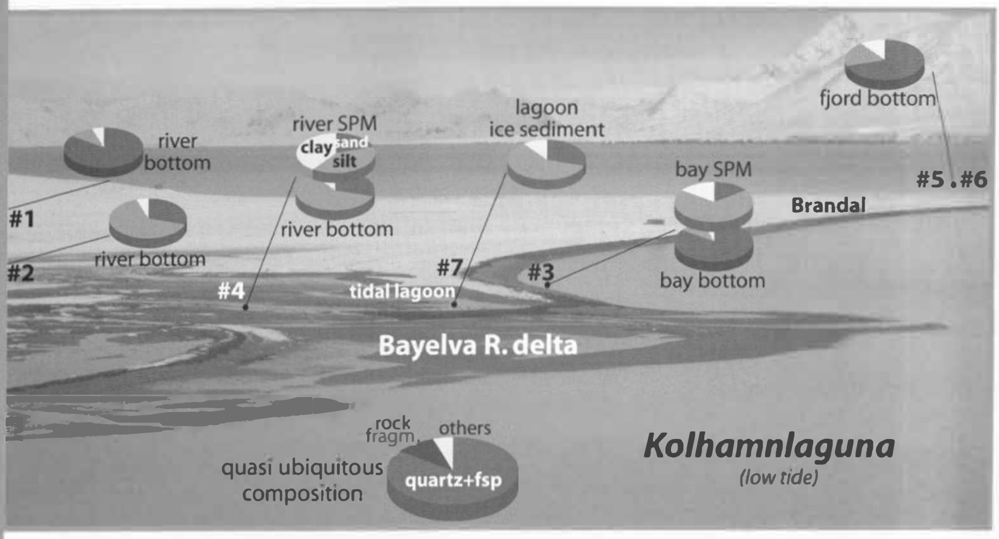

Figure 10 *Sand, silt and clay distribution of bottom sediments, SPM and lagoon ice sediments at various stations. Quasi-ubiquitous mineralogical composition is given in the lower large pie diagram (see text for more details). Note that station #1 and #2 are located few hundred meters up-river.*

SPM – Linkage between terrestrial discharge and littoral deposits?

Suspended particle concentrations obtained at Brandalpynten (stations #5, #6) from Niskin bottle sampling varied between ~2.6 mgl^{-1} at the surface and ~1.2 mgl^{-1} close to the bottom (Table III, see Annex). We assume that this particular vertical distribution of particles in the local water column with higher values at the surface and lower concentrations at the bottom originated from the still strong fall terrestrial discharge. Aeolian transport of terrestrial surface particles into the adjacent fjord could be widely excluded due to snow coverage (Fig. 10). The hydrological influence of terrestrial discharge could also be traced from lower surface salinities (Fig. 11).

Like in the river mouth and the bay environment, the suspended material trapped at Brandalpynten (Fig. 11; Table III and IV, see Annex) over a period of about 24 hrs was mostly fine grained (silt and clay), and also dominated by to as

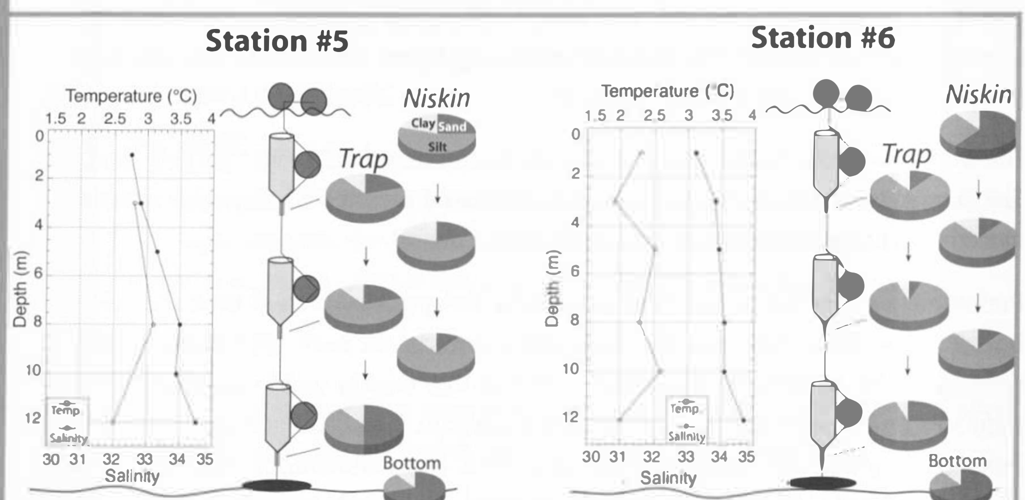

Figure 11 *Grain size distributions (pies) of suspended particulate matter ('Niskin'), sediment trap material ('Trap') and bottom deposits ('Bottom'), and temperature/ salinity profiles at station #5 (left) and station #6 (right).*

much as 90-95% of terrestrial material consisting widely of reddish quartz particles. Marine particles like diatoms were of minor abundance or infrequent. On contrary to the suspension load sampled by Niskin bottle and the sediment traps, the Brandalpynten bottom deposits were rather sandy and contained slightly less reddish quartz particles.

From our findings we suppose that both suspended material and bottom deposits around Brandalpynten are also widely dominated by the characteristic reddish terrestrial particle supply of the Bayelva river. Thus, the terrestrial discharge seems to influence parts of the southern fjord shore at least west of Ny Ålesund. Marine particles are of minor importance in local suspension load and littoral deposits, though the shore regime is regularly influenced by tidal dynamics.

Lagoon ice – temporary sediment storage or factor of erosion?

The floating level ice floes sampled in the small tidal lagoon of the Bayelva river mouth were about 5 cm thick, had a rough underside and a porous structure. The ice surface was covered by a layer of ~1 cm frozen snow. Floe diameters varied between 20 cm and 100 cm.

The ice contained visible fine-grained, reddish sediment particles concentrated in small patches or aggregates (Fig. 12). The particulate ice sediment load averaged from three individual filters (Table III, see Annex) was 1271.62 mgl^{-1}.

The visual estimate (binocular) of the grain size distribution in lagoon ice sediment reveals 30% sand-sized material, 60% silt and 10% clay (averaged from three lagoon ice samples; Table II, see Annex). Quartz and feldspar grains were the most abundant particle groups in the ice sediment (up to 95%), while other minerals and biogenic material were less abundant or infrequent. Quartz particles of either size contained reddish inclusions or were covered by reddish coatings of probably iron oxide.

Figure 12 *Ice slices stored in a beaker for melt. See PE bottle lit (diameter ~4 cm) in the upper left corner for scale.*

The porous structure of the lagoon-ice floes resembled bottom-released anchor ice known e.g. from Laramie River (WY, USA). However, coarse-grained sediment from the bottom - which is characteristic to be incorporated in anchor ice (Reimnitz et al. 1992; Kempema et al. 1989) - was missing in the lagoon ice. We thus suggest that the sediment-laden lagoon ice formed under turbulent conditions by the process of suspension freezing (Fig. 13), supported by enrichment and filtration trapping mechanisms proposed by Osterkamp & Gosink (1984), which may partly be driven by Lc (Dethleff 2005, Kempema & Dethleff 2006, Dethleff & Kempema 2007). We suspect that sediment-laden lagoon ice may either act as temporary sediment storage, which releases its particle load again during day melt, or even may enhance erosion of fine grained coastal material through the release of sediment-laden ice towards the deeper Fjord. Spring break-up of a particle-rich Kongsfjord ice canopy after permanent winter freezing conditions may significantly enhance coastal erosion and subsequent sediment transport towards the Northern Atlantic Ocean. The process of coastal erosion by sediment entrainment into newly forming sea ice was e.g. suggested by Dethleff (2005) for the shallow Siberian Laptev Sea, and described by Reimnitz et al. (1988, 1993a) for the North American Arctic.

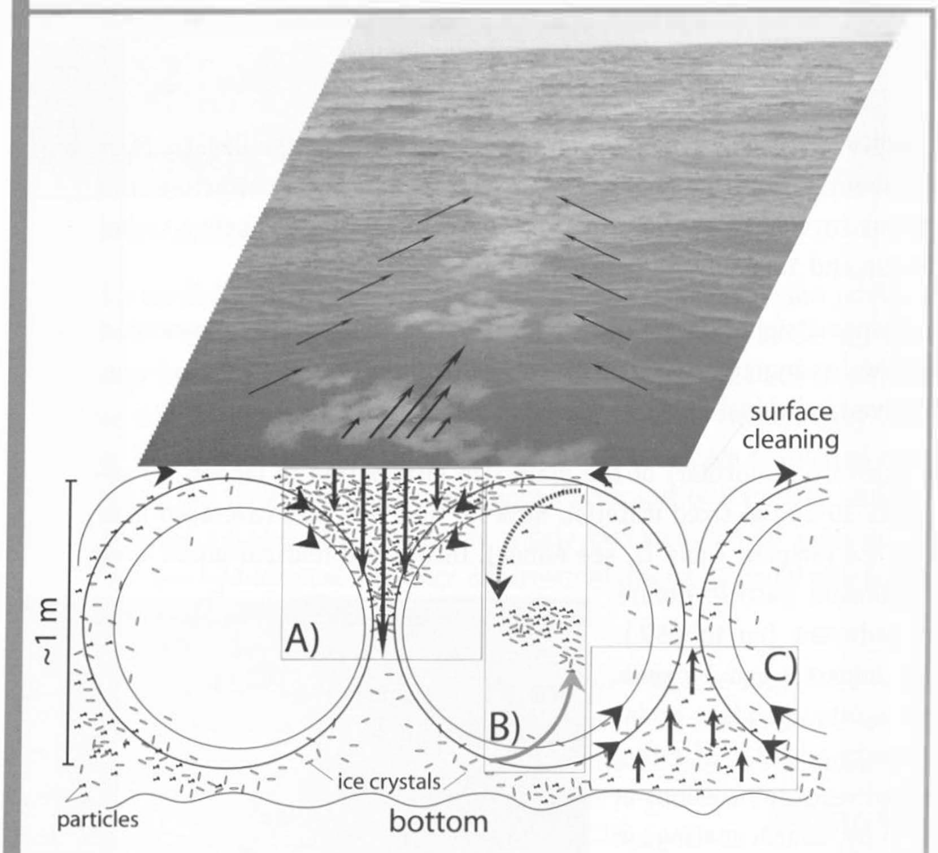

Figure 13 *Schematized Lc-supported process of suspension freezing (interaction of ice crystals and sediment particles in the turbulent water column), and entrainment of fine-grained particulate material into newly forming lagoon ice in the Bayelva River mouth. A - denotes a Lc surface convergent zone with filtration trapping of particles in frazil ice, B - displays the sprinkle of settling sediment particles over buoyant uprising frazil injected from below, and C - shows a Lc bottom convergent zone with scavenging of sediment particles from the water column by uprising frazil.*

Marine macroalgae summer particle load – Burden or challenge?

Fragmented and complete *L. saccharina* from stations #10 and #8 are shown in Figure 14 A and B. Part C of the figure displays fragments of *S. dermatodea* from station #7. Algae phyloid surfaces reveal thin coatings or patches of sediment.

The sediment coatings of all algae were composed to as much as 85-90% of silt and clay (Table II, see Annex). Sand was less abundant or infrequent in the algae sediment covers. On contrary, the local bottom sediment deposits at the algae sampling sites were composed of sand dominated material. This may indicate that rather silt and clay are attached to algae surfaces directly from suspension or during deposition on the sea bottom, while sand was either currently not transported in the regime or was not deposited and attached on the algae surfaces.

Like all sedimentological compartments discussed before, the qualitative composition of the algae particle coverage is dominated by 90-95% of the reddish quartz particles originating from Bayelva river (Tabe II, see Annex). The characteristic composition of algae surface sediments indicate that the terrestrial particle discharge also strongly influences local macroalgae stocks and habitats. However, sediment-induced potential burdens, control mechanisms or even challenges on the algae related e.g. to the physiology, light regime, UV protection, photosynthesis, pre-adaptation to winter darkness, productivity, sporulation, and habitat changes are widely unknown yet.

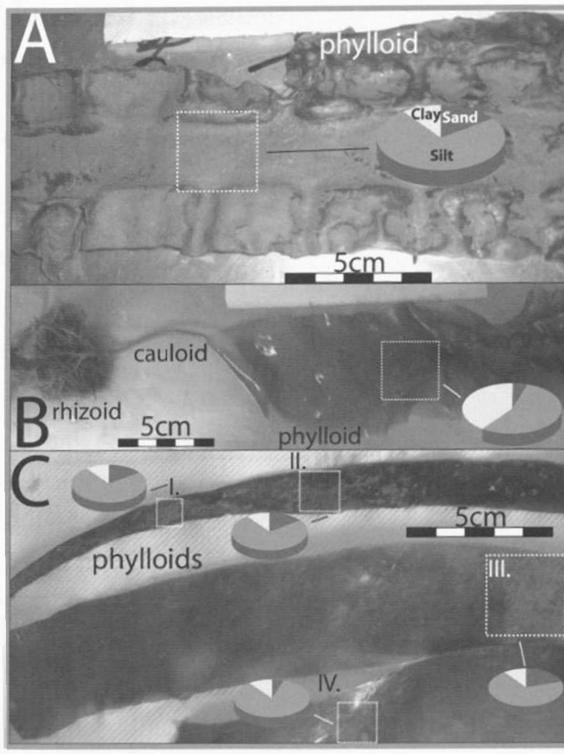

Figure 14 *Complete and fragmented algae. See stippled white boxes for particle coverages, which were sampled for sedimentological investigations (A- Thiisbukta, L. saccharina; B – Kolhamnlaguna, L. saccharina; C – Bayelva river mouth, S. dermatodea).*

Tank experiments – Lc and sediment-ice-algae interactions

Lc experiments

Interfering wind-wave action superimposing with the wind-induced tank primary flow produced Langmuir circulation in tank experiment #1. The circulation cells generated in the basin could be traced from two broad streaks of a thin tank floor sediment layer collected in the bottom convergent zones of paired converging Lc vortices (Fig. 15). The bottom streaks migrated upwind, driven by the interplay of the tank bottom return flow and the secondary Lc flow. From the number of bottom sediment streaks (2), four converging Lc vortices (2 Lc cells) could be inferred (Fig. 15C).

Particles sampled from three different sites in the upwind migrating bottom sediment streaks (see Asterisks in Fig. 15B) in experiment #1 indicate that the particle size decreases with increasing distance from the sediment input line (Table II, see Annex). This reveals that the bottom return flow and the superimposing Lc secondary-flow in the tank experiments rather transport fine-grained particles over longer distances. Coarser - and thus more dense and heavier - particles could not be far dislocated from the sediment input line by return flow and Lc.

Besides the tank SPM, tank ice sediments reveal the finest particle composition of all compartments sampled during experiments #1 and #2. Moreover, particle concentrations in the ice are clearly enriched compared to the tank water (Table III, see Annex). These findings well reflect results from various other tank studies (Reimnitz et al. 1993b, Smedsrud 2001, Dethleff & Kempema 2007) and from investigations in the Central Arctic (Kempema et al. 1989, Dethleff 2005). Lc-related processes of turbulent ice-sediment entrainment in the tank experiments are supposed to be similar to those mechanisms suggested for natural settings as displayed in Figure 13.

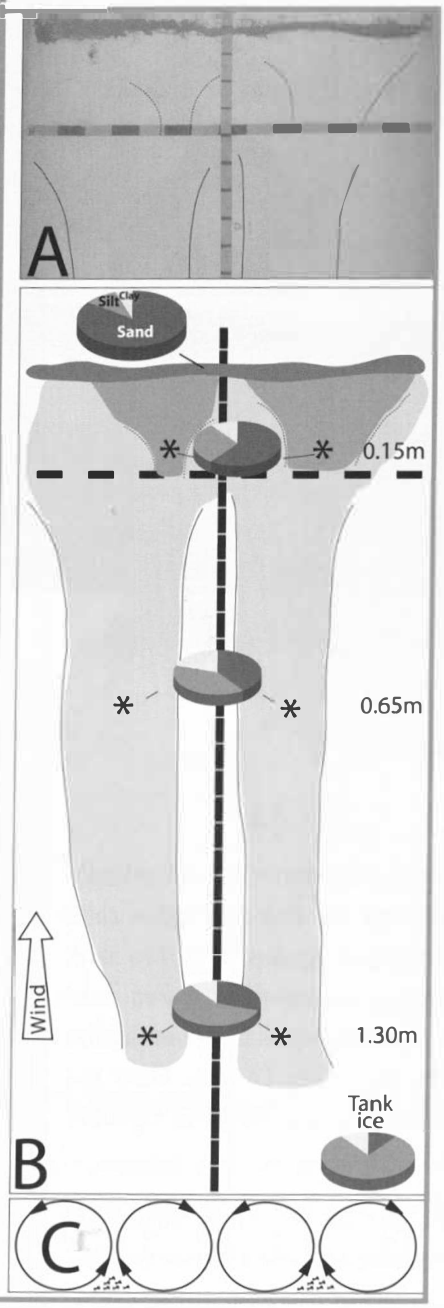

Figure 15 *Tank top-view showing upwind bottom sediment migration of fine grained sediment particles (A, B) through Lc (C).*

In experiment #3, the Lc flow was visualized by potassium permanganate dye floating in the tank. Cork screw-like bands in the water column indicated helical upwind Lc motion generated by superimposition of primary flow and wind-wave action.

Algae experiments

During the run of experiment #4, the in-line arranged and sediment-covered algae (Fig. 16A and B) were agitated by tank-internal current patterns like primary flow and Lc. This could be suggested from semi-circular bottom traces (Fig. 16C) indicating lateral algae drift around the bottom mooring-point of the algae rhizoid. Current and turbulence patterns induced in the tank may contribute to clean the algae from parts of the particulate material.

After four days of algae exposure to the artificial sediment coverage, the algae were recovered from the tank bottom and cleaned from the superficial sediment by prudently affecting the leave in the tank water. The remaining patchy sediment coatings (Fig. 16D) were composed of about 65% sand-sized material and 35% fine-grained particles (Table III, see Annex), which well reflects the grain size distribution of the sediment originally placed on the tank algae. We suggest that sediment particles may be fixed on macroalgae surfaces after at least few days of sediment exposure. Saccharin slime released from the algae surface may support the attachment of sediment particles.

Ice formed in the tank during the last night of the experiment and was sampled in the next morning. The ice sediment composition was dominated by sand, while the SPM predominantly contained silt-sized material. All compartments sampled revealed high percentages of reddish quartz particles.

Man-made radionuclides – Tracers for human activities?

The water samples will be analyzed for radionuclides and results will be expected soon.

ADCP recording – Tracing tidal currents and Langmuir circulation?

The ADCP data are still under processing and results will be expected soon.

Meteorological data – Support for understanding the fjord regime

Meteorological data are still under processing and results will be expected soon.

UV radiation tank measurements – Influenced by ice?

As shown in Table 1, the PAR irradiance in open tank water conditions is identical to the measurement in the under ice conditions. UVB irradiance is also in the same range both under ice and in open water conditions, indicating that thin layers of clear sea ice only have small effect on the attenuation of light.

However, the UVA record is slightly higher in the under ice measurement than in open water. This might be due to the time shift between the measurements, permitting changes in the solar radiation. Possibly, a thin layer of frazil ice crystals might have an intensity-increasing and wave length-dependent lens-effect, which needs further investigations to be proved.

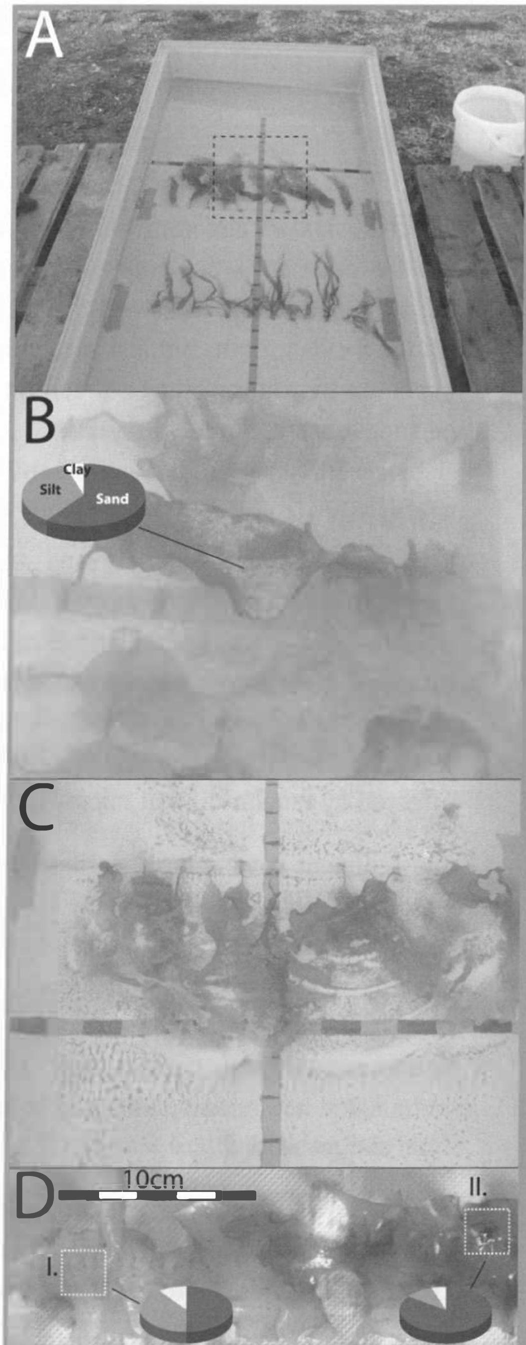

Figure 16 *Juvenile L. saccharina in the experiment basin (A) with artificial surface sediment load (B), partly surface sediment release by current-induced lateral motion (C), and residual particle cover after algae sampling (D).*

Table 1 PAR (µmol m^{-2} s^{-1}) and UV (Wm^{-2}) measurements.

	Open water	
PAR	UVA	UVB
135	3.15	0.11
	Under Ice	
PAR	UVA	UVB
135	3.29	0.09-0.12

In conclusion we can state that a thin ice-cover insignificantly attenuates PAR and UV radiation in our tank experiment. As known from other studies, depending on structure and thickness the sea-ice and snow cover does not only diminish the incident light, but also alters the radiation spectrum by favouring and/or impeding the transmittance of certain wavelength ranges (Gerland et al. 1999; personal observations L. Brey).

Summary, Conclusions and Outlook

Briefly summarizing our data and results from the AWIPEV-INVEST 2005, we can state that during late summer and fall 2005 the sedimentological regime of Kolhamnlaguna was widely influenced by the characteristic terrestrial particle discharge from Bayelva river, which is mainly composed of reddish quartz particles containing iron-oxide inclusions or coatings. Marine particles are widely less abundant in suspension and surface deposits, though Kolhamnlaguna is affected by regular diurnal micro- to mesotidal cycles.

The sediment coverage on marine benthic macroalgae in various environments like Bayelva river mouth lagoon, Kolhamnlaguna, and Thiisbukta is also composed of terrestrial debris dominated by reddish quartz particles. Our algae tank experiments show that an artificial sediment load over a period of about four days may produce particle coatings on formerly 'clean' tank algae. Wind-wave action and Langmuir circulation (Lc) may play a major role in agitation of algae in tank and nature, and must thus be regarded as potential cleaning mechanisms from sediment load.

In final conclusion, Kolhamnlaguna and both the adjacent Bayelva river mouth and shallow Thiisbukta are suitable sites to study sediment and macroalgae interactions in a micro- to mesotidal Arctic littoral regime. Moreover, marine bio-sedimentological processes occurring in the shallow bay could be satisfactory simulated in outdoor experiment basins close to the ancient Ny Ålesund pier.

Looking out from today toward the next years, one of the main goals is to further strengthen and develop the joint French-German research efforts in Ny Ålesund between the 'Institute for Polar Ecology' at the University of Kiel, the 'Laboratoire de Morphodynamique Continentale et Côtière' at the University of Rouen, the 'Alfred-Wegener-Institute for Polar and Marine Research', the 'Department of Marine Botany' at the University of Bremen, and the 'ThéMA-CNRS' at the University of Besançon. Particular research goals contain to compare and to better understand various littoral sites on the southern Kongsfjorden shore in terms of terrestrial particle supply, marine sedimentology, marine bentic macroalgae biology, and shallow water hydrodynamics.

Acknowledgments

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Annex

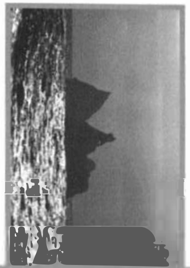

Table 1: *Station list.*

Station #	date	Latitude	Longitude	Location	Water depth (m)	Type of samples	Ice type	Ice relief	Ice thick-ness (cm)	Floe-size (m)	ca. Water salin.	ca. Wa-tertemp. (°C)
1	9/13/2005	78°56.25'N	11°51.60'E	Bayelva river	0	bottom sediment	-	-	-	-	-	-
2	9/13/2005	78°56.25'N	11°51.60'E	Bayelva delta	0	bottom sediment	-	-	-	-	-	-
3	9/13/2005	78°56.25'N	11°51.60'E	Kolhamnlaguna	0.8	bottom sed., water	-	-	-	-	-	2.3
4	9/13/2005	78°56.25'N	11°51.60'E	Bayelva delta	0.05	bottom sed., water	-	-	-	-	-	-0.3
5	9/14/2005	78°56.87'N	11°51.64'E	Brandalpynten	13	bott. sed., SPM, sed. trap	-	-	-	-	32.5 - 33.9	2.5 - 3.1
6	9/18/2005	78°56.87'N	11°51.64'E	Brandalpynten	13	bott. sed., SPM, sed. trap	-	-	-	-	33.9 - 34.1	2.3 - 2.6
7	9/18/2005	78°56.25'N	11°51.60'E	Bayelva delta	0.8	bott. sed., ice, algae	drift	level,rubble,	5-6	0.5-1	~20	at freezing
8a	9/19/2005	78°56.15'N	11°51.80'E	Kolhamnlaguna	~6	bott. sed., SPM, algae	-	-	-	-	-	-
8b	20-21/9/2005	78°55.84'N	11°53.98'E	Kolhamnlaguna	5,1	ADCP*	-	-	-	-	-	-
9	9/20/2005	78°56.87'N	11°51.64'E	Brandalpynten	13.5	sea water	-	-	-	-	34,4	~3.2
10	9/20/2005	78°55.50'N	11°53.98'E	Thiisbukta	0	beach sediment, algae	-	-	-	-	-	-

Tank #	date	Latitude	Longitude	Location	Water depth (m)	Type of samples	Ice type	Ice reli-ef	Ice thick-ness (cm)	Floe size (m)	ca. Water salin.	ca. Water temp. (°C)	Wave period (Hz)	Wave length (cm)	Wave height (cm)
1	13-14/09/2005 (8pm - 10.30am)	78°55.60'N	11°52.00'E	old pier, NÅ	0.15	ice, water, bott. sed.	nilas	level	~0.5-1	-	-	start: 2.0 end: -1.3	video	~4	~1
2	14-15/09/2005 (8.30pm - 11am)	78°55.60'N	11°52.00'E	old pier, NÅ	0.15	ice, water	nilas	level	~0.5	-	~32.0	start: 1.2 end: -0.8	-	-	-
3	9/16/2005 (3pm - 3.35pm)	78°55.60'N	11°52.00'E	old pier, NÅ	0.11	-	-		-	-	~31.8	start: 0.5 end: 0.5	video	~2-3 ~5-6 down-wind	~1
4	17-20/09/2005 (8pm - 10.30am)	78°55.60'N	11°52.00'E	old pier, NÅ	0.16	ice, water, algae, sed.	nilas	level	~0.8-1.5	-	~32.6	start: 1.0 end: -	video	video	~1

*Acoustic Doppler Current Profiler

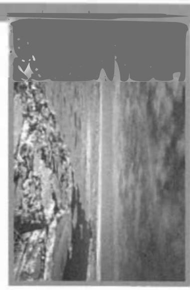

Table 1: *Station list (continued).*

Table 2: *List of sampled material.*

Station/ Experiment	Sample Type	Grain size distrib. Sand (%)	Silt(%)	Clay(%)	Sample Composition Quartz and Feldspar	Rockfragments	Darkminerals	(%)Mica	Biogenic	Plant Debris	Others	Remarks
station 1	bottom sediment a	85	10	5	~90	~10	tr.	tr.	tr.	tr.	tr.	
station 2	bottom sediment a	30	65	5	~95	tr.	tr.	tr.	tr.	tr.	tr.	
station 3	bay water b	15	70	15	~90	tr.	tr.	tr.	tr.	tr.	tr.	
station 3	bottom sediment c	85	10	5	~70	~15	~15	tr.	tr.	tr.	tr.	
station 4	river discharge b	20	40	40	-	-	-	-	-	-	-	
station 4	bottom sediment a	30	60	10	~95	tr.	tr.	tr.	tr.	tr.	tr.	
station 5	Niskin bottle, upper level b	25	55	20	~90	tr.	tr.	tr.	tr.	tr.	tr.	
station 5	Niskin bottle, mid level b	20	60	20	~90	tr.	tr.	tr.	tr.	tr.	~5	
station 5	Niskin bottle, lower level b	10	80	10	~90	tr.	tr.	tr.	tr.	tr.	~5	
station 5	sed. trap (10m above ground) a	20	70	10	~90	tr.	tr.	tr.	tr.	tr.	tr.	very fine matrix; angular-sub-rounded, reddish large quartz particles
station 5	sed. trap (5m above ground) a	20	70	10	~90	tr.	tr.	tr.	tr.	tr.	tr.	
station 5	sed. trap (1m above ground) a	50	40	10	~90	tr.	tr.	tr.	tr.	tr.	tr.	
station 5	bottom sediment c	70	20	10	~80	~10	~5	tr.	tr.	tr.	tr.	
station 6	Niskin bottle, upper level b	60	30	10	~90	tr.	tr.	tr.	tr.	tr.	tr.	
station 6	Niskin bottle, mid level b	10	80	10	~90	tr.	tr.	tr.	tr.	tr.	tr.	
station 6	Niskin bottle, lower level b	10	80	10	~90	tr.	tr.	tr.	tr.	tr.	tr.	
station 6	sed. trap (10m above ground) a	10	80	10	~95	tr.	tr.	tr.	tr.	tr.	tr.	
station 6	sed. trap (5m above ground) a	5	90	5	~95	tr.	tr.	tr.	tr.	tr.	tr.	
station 6	sed. trap (1m above ground) a	25	70	5	~95	tr.	tr.	tr.	tr.	tr.	tr.	
station 6	bottom sediment c	70	20	10	~80	~10	~5	tr.	tr.	tr.	tr.	
station 7	lagoon ice a) a	60	30	10	~95	tr.	tr.	tr.	tr.	tr.	tr.	
station 7	lagoon ice b) a	15	75	10	~95	tr.	tr.	tr.	tr.	tr.	tr.	
station 7	lagoon ice c) a	20	70	10	~95	tr.	tr.	tr.	tr.	tr.	tr.	
station 7	~average: lagoon ice a-c a	30	60	10	~95	tr.	tr.	tr.	tr.	tr.	tr.	
station 7	coating S. dermatodea lagoon; I. a	15	75	10	~95	tr.	tr.	tr.	tr.	tr.	tr.	
station 7	coating S. dermatodea lagoon; II. a	15	75	10	~95	tr.	tr.	tr.	tr.	tr.	tr.	
station 7	coating S. dermatodea lagoon; III. a	20	70	10	~95	tr.	tr.	tr.	tr.	tr.	tr.	

Table 2: *List of sampled material (continued).*

station 7	coating S. dermatodea lagoon; IV. a	5	85	10	~95	tr.	tr.	tr.	tr.	tr.	tr.	
station 7	~average: coating S. dermatodea I-IV. a	15	75	10	~95	tr.	tr.	tr.	tr.	tr.	tr.	
station 7	lagoon bottom sediment d	>98	<1	<1	~5	~90	tr.	tr.	tr.	tr.	tr.	mostly gravel, angular to subrounded
station 8	coating L. saccharina, sea floor a	5	55	40	~90	tr.	tr.	tr.	~5	tr.	tr.	
station 8	L. saccharina, surround. water a	15	70	15	~80	tr.	~3	~3	~5	~5	~3	
station 8	bottom sediment c	70	20	10	~80	~10	~5	tr.	tr.	tr.	tr.	
station 10	coating L. saccharina, beach a	15	75	10	~95	tr.	tr.	tr.	tr.	tr.	tr.	
station 10	beach sediment d	70	30	10	~5	~90	tr.	tr.	tr.	tr.	tr.	much gravel, angular to subrounded
tank exp. 1	tank ice b	10	80	10	~95	tr.	~5	tr.	tr.	tr.	tr.	
tank exp. 1	floor sediment (0.15m) b	60	30	10	~80	~10	~3	~3	tr.	tr.	tr.	
tank exp. 1	floor sediment (0.65m) b	40	40	20	~80	~5	~5	~3	~3	~3	tr.	
tank exp. 1	floor sediment (1.3m) b	30	60	10	~70	~5	~5	~3	~3	~3	~10	fibrous material
tank exp. 1	tank water SPM b	10	80	10	~90	tr.	~3	tr.	tr.	tr.	tr.	
tank exp. 1	floor sediment (Bayelva r. stat. 1) a	85	10	5	~90	~10	tr.	tr.	tr.	tr.	tr.	
tank exp. 2	tank ice b	40	40	20	~80	~5	~5	tr.	~5	~5	tr.	
tank exp. 2	tank water SPM b	20	60	20	~90	tr.	~3	tr.	~3	tr.	tr.	
tank exp. 2	floor sediment (Bayelva r. stat. 2) a	30	65	5	~95	tr.	tr.	tr.	tr.	tr.	tr.	
tank exp. 4	tank ice b	60	30	10	~60	~10	~10	tr.	~5	~3	~10	
tank exp. 4	coating L. saccharina, tank floor, I. a	50	40	10	~95	tr.	tr.	tr.	tr.	tr.	tr.	
tank exp. 4	coating L. saccharina, tank floor, II. a	85	10	5	~95	tr.	tr.	tr.	tr.	tr.	tr.	
tank exp. 4	~average: coating L. saccharina, I-II. a	65	25	10	~95	tr.	tr.	tr.	tr.	tr.	tr.	
tank exp. 4	initial tank water SPM b	10	80	10	~80	~3	~3	~3	~3	~3	~5	
tank exp. 4	floor sediment (~average: Bayelva r. stat. 1+2) a	55	40	5	~92	~5	tr.	tr.	tr.	tr.	tr.	

a =determined by microscopic smear slide analysis (128 to 320-fold magnification)
b =determined by binocular filter material analysis (40-fold magnification)
c =determined by binocular scatter preparation analysis (40-fold magnification)
d =sand and gravel (visual)
tr. = traces

Table 3: *List of particles in suspension and sea ice.*

Station/ Experiment	Sample type	Sample weight (mg)	Water vol. (ml)	Particles (mg/l)	Enrichment Ratio
station 3	bay water	5,05	1060	4,76	-
station 4	river discharge	1,291	940	1,37	-
station 5	Niskin bottle, upper level	2,336	1030	2,27	-
station 5	Niskin bottle, mid level	1,847	1000	1,85	-
station 5	Niskin bottle, lower level	1,267	1071	1,18	-
station 6	Niskin bottle, upper level	2,658	1020	2,61	-
station 6	Niskin bottle, mid level	1,277	1011	1,26	-
station 6	Niskin bottle, lower level	1,465	1004	1,46	-
station 7	lagoon ice a)	2777,112	1080	2571,40	-
station 7	lagoon ice b)	329,056	1049	313,69	-
station 7	lagoon ice c)	556,009	598	929,78	-
tank exp. 1	tank ice	6,458	1940	3,33	2,19
tank exp. 1	tank water SPM	1,465	965	1,52	-
tank exp. 2	tank ice	1,29	103	12,52	14,23
tank exp. 2	tank water SPM	0,91	1030	0,88	-
tank exp. 4	tank ice	6,614	1430	4,63	0,39
tank exp. 4	initial tank water SPM	12,31	1035	11,89	-

Table 4: *List of sample weights.*

Filter no.	Station/ Experiment	Sample type	Filter Tara (mg)	Filter full (mg)	Sample weight (mg)	Volume filtered (ml)	Particle conc. (mg/l)
287	station 3	bay water	95,165	100,215	5,050	1060	4,76
288	station 4	river discharge	96,733	98,024	1,291	940	1,37
289	tank exp. 1	tank water SPM	96,453	97,918	1,465	965	1,52
290	tank exp. 1	floor sediment (1.3m)	94,106	157,030	62,924	-*	-*
291	tank exp. 1	floor sediment (0.65m)	94,269	112,595	18,326	-*	-*
292	tank exp. 1	floor sediment (0.15m)	95,552	126,913	31,361	-*	-*
293	tank exp. 1	tank ice	96,677	103,135	6,458	1940	3,33
294	station 5	Niskin bottle, upper level	92,931	95,267	2,336	1030	2,27
295	station 5	Niskin bottle, mid level	93,563	95,410	1,847	1000	1,85
296	station 5	Niskin bottle, lower level	91,886	93,153	1,267	1071	1,18
297	tank exp. 2	tank water SPM	92,593	93,503	0,910	1030	0,88
298	tank exp. 2	tank ice	96,151	97,441	1,290	103	12,52
299	station 5	sed. trap (1m above ground)	94,991	387,738	292,747	-*	-*
300	station 5	sed. trap (5m above ground)	96,489	505,894	409,405	-*	-*
301	station 5	sed. trap (10m above ground)	99,020	627,070	528,050	-*	-*
302	tank exp. 4	initial tank water SPM	94,440	106,750	12,310	1035	11,89
303	station 6	Niskin bottle, upper level	94,160	96,818	2,658	1020	2,61
304	station 6	Niskin bottle, mid level	97,237	98,514	1,277	1011	1,26
305	station 6	Niskin bottle, lower level	94,860	96,325	1,465	1004	1,46
306	station 7	lagoon ice a)	92,488	2869,600	2777,112	1080	2571,40
307	station 7	lagoon ice b)	93,724	422,780	329,056	1049	313,69
308	station 7	lagoon ice c)	95,081	651,090	556,009	598	929,78
309	station 6	sed. trap (1m above ground)	94,937	325,800	230,863	-*	-*
310	station 6	sed. trap (5m above ground)	97,084	553,290	456,206	-*	-*
311	station 6	sed. trap (10m above ground)	98,209	294,430	196,221	-*	-*
312	station 10	sediment Laminaria saccharina, beach	96,793	1850,800	1754,007	-*	-*
313	station 8	Laminaria saccharina, surround. water	94,059	121,220	27,161	-*	-*
314	tank exp. 4	tank ice	95,079	101,693	6,614	1430	4,63

*no volume and particle concentration determined due to sample type