ASOF-N

Arctic-Subarctic Ocean Flux Array for European Climate: North

REPORT

of the 3rd ASOF-N Seminar

8-9 December 2005

Bremerhaven, Germany

Agenda Final ASOF-N Seminar 08 December 2005 in Bremerhaven

09:00-09:15	Introduction	Eberhard Fahrbach
09:15-09:45	ASOF: synthesis and perspectives	Bob Dickson
09:45-10:15	WP1: Atlantic water pathways: three years of synoptic observations	Jan Piechura/ Waldemar Walczowski
10:15-10:45	WP1: Results from floats in ASOF-N	Jean-Claude Gascard
10:45-11:00	WP2: A brief overview on IMR activities in ASOF-N	Harald Loeng
11:00-11:30	Coffee	
11:30-12:00	WP1/WP2: Current measurements in the Norwegian Sea	Kjell Arne Mork
12:00-12:30	WP2 Results from current measurements at BSO	Øystein Skagseth
12:30-13:00	WP3 Variability of heat transport through Fram Strait – Observations	Agnieszka Beszczynska-Möller
13:00-14:00	Lunch	
14:00-14:30	WP3 Modelling Fram Strait exchange processes	Kerstin Fieg
14:30-15:00	WP4 Overview on WP4 achievements	Edmond Hansen
15:00-15:30	WP4 Liquid freshwater fluxes through Fram Strait	Jürgen Holfort
15:30-16:00	Recent changes at the 74°N section observed by SFB 512	John Mortensen
16:00-16:30	Coffee	
16:30-17:00	The structure and changes in the EGC from 1985 to 2000 as observed in the Fram Strait.	Svein Osterhus
17:00-17:30	MOEN Status and some scientific results	Svein Osterhus
17:30-18:00	ASOF-EC-W-Status report	Jens Meincke
19:00	Dinner	

09 December 2005 in Bremerhaven

09:00-09:30	WP5: Data management, ASOF-N Web site	Gerd Rohardt
09:30-10:30	WP6: Integration and synthesis	Bert Rudels
10:30-11:00	Coffee	
11:00-11:40	Technological Implementation Plan (TIP)	Rebecca Ludwig
11:40-12:00	Report and Closing	Eberhard Fahrbach

The seminar was opened on Thursday, December 8, with a short welcome by the Coordinator of ASOF-N project, *Eberhard Fahrbach.* The updated agenda was briefly discussed and hausekeeping issues were addressed. A list of participants can be found in Appendix 1. The opening talk by Bob Dickson, International ASOF Coordinator, was focused on the synthesis and future perspectives of the ASOF project.

The first presentation on the ASOF-N **WP1** results, 'AW pathways: 3 years of synoptic observations' was given by *Waldemar Walczowski* (IOPAN). First he presented in details the results obtained in summer 2005 in the Greenland Sea and Fram Strait and next compared them to the earlier observations during the ASOF period. In June-July 2005 12 sections measured by RV 'Oceania' included 200 CTD stations and 193 lowered ADCP (LADCP) profiles together with continuous measurements of upper layer currents by the vessel-mounted ADCP. The horizontal distributions of temperature at 100 db the Atlantic Water (AW) mean temperature and thickness were shown together ADCP-measured and baroclinic geostrophic currents. There are two distinct maxima manifested in the distribution of the geostrophic flow kinetic energy, related to the main core and the western branch of the AW flow. A convergence of these streams was found at 78°N. Strong meandering of the western branch was also observed with the strongest recirculation patterns located at 78°N and 79°N. A high correlation between geopotential anomaly, geostrophic currents pattern and bottom topography suggested a strong topographic steering in the West Spitsbergen Current (WSC). Vertically integrated transport of the AW at succeeding sections west of Svalbard showed the eastern branch (core of the WSC) inflowing to the Arctic Ocean and the western branch almost exclusively recirculating in the Fram Strait. Horizontal fields of temperature and heat content of the AW layer during the ASOF-N period reveal the strong warming and increase in the heat flux in 2004 and 2005. The temperature and baroclinic currents anomalies from 6-year summer mean show the warmer than average AW entering the Barents Sea in 2002 and anomalously warm AW propagating northward into Fram Strait in 2004 and 2005. The selected results from the high resolution numerical model (NPS 9-km model) were used to show that northward volume transport and northward AW transport through Fram Strait are well represented by transports across the eastern part of the strait, which is covered by observations. The model results reveal also that the northward and southward volume fluxes through Fram Strait are highly correlated.

Presentation of the **WP1** achievements was continued by *Jean-Claude Gascard* (LODYC) who presented the results from floats and three hydrographic sections (Bjornoya, Fugloya, Gimsoy). The main issues addressed in his talk included AW pathways, transports across sections and water masses transformation between sections. Deployment locations and tracks of the floats launched during ASOF-N were shown. The 'spaghetti diagrams' illustrated paths of the 300m depth floats in the Lofoten Basin for three ASOF deployment periods: April to September 2003, April to August 2003 and October 2003 to January 2004. The most prominent observed circulation pattern included a presence of strong and persistent mesoscale eddies, which were visible from trajectories of floats as well as in the horizontal temperature fields. Cyclonic eddies were characterized by cold cores while anticyclonic gyre was filled with warm waters. Distributions of temperature, salinity and tracer concentration (Iodine, $I^{129}/I^{127} \cdot 10^{-10}$) at three main hydrographic sections showed the location of the AW main streams and intensity of mixing between different water masses. A concentration of the tracer at different depths was the highest within the Norwegian Coastal Current at the Gimsoy and Fugloya sections while its relative maximum down to 500 m at the Bjornoya section was related to the topographically steered AW flow in the northward branch of the Norwegian Atlantic Current (NwAC). A closed circulation pattern around the Lofoten Basin was also confirmed by measurements with ARGO floats in August 2003-October 2005. The observed structure with horizontal scale of 100 km and depth 500 m was characterized by a mean speed 0.16 cm/s and transported ca. 8 Sv of water. The comparison of temperature and salinity sections from 2000, 2003 and 2004 at Gimsoy and Bjornoya indicated a strong warming and salinification of AW in the last two years. The transport through the Gimsoy section based on LADCP measurements was estimated as 8.2 Sv with additional 1.2 Sv in the coastal current. Geostrophic baroclinic estimates of transport related to 700m for 2000, 2003 and 2004 were significantly lower and decreasing from year to year. A role of the eddy transport, eddy kinetic energy and eddy mixing/diffusivity was stressed and pointed as the future challenge which can be effectively measured only by a combination of Lagrangian (drifters), Eulerian (moorings) observations, hydrological sections (gliders) and tracers.

Harald Loeng (IMR) gave a brief overview on the IMR activities in ASOF-N **WP2**. The array of 7 moorings in the Barents Sea Opening (Fugloya-Bjornoya section) which has been operated during the ASOF period was complemented by hydrographic sections repeated up to six times per year. It was shown that the part of the NwAC which enters the Barents Sea, called the North Cape Current (NCaC), is getting warmer and wider under stronger southwesterly winds when the stronger velocities result in the higher transport. The NCaC has a two-core structure during warm periods and one wider core in the cold ones. Anomalies of temperature and salinity based on hydrographic measurements were presented for the period 1977-2005 with the last warm anomaly lasting continuously since 1998. With short exceptions the salinity anomaly was also positive in this last period. It was also shown that mean temperature at the Bjornoya-Fugloya section and the volume of AW (defined as T>5°C) are closely correlated. AW inflow (T>3°C) through the section estimated from mooring data had maxima in 1998 and early 2003 and after a decrease in 2003-2004 seems to be growing again. There is no significant correlation found between the temperature anomaly and volume flux measured by the moored array. Some extra moorings and current meters were deployed during ASOF-N in 2003-2005 in the eastern part of the Norwegian Basin and the Greenland Sea (moorings M1 to M15). Mean velocities of currents measured at different depths (500m, 1000m and 2000m) were shown as a preliminary result. The high resolution implementation of the ROMS model for the Barents Sea was also presented with a focus on comparison between modelled and measured fluxes. The model results revealed that the flow in the western Barents Sea is highly variable on a daily time scale with inflow/outflow up to 13/13 Sv and a maximum daily variation of 10 Sv. Examples of SST and ice concentrations fields for the high resolution set-up (grid ca. 10 km) were also shown to be in a good agreement with observations.

The results of current measurements in the Norwegian Sea were described by *Kjell Arne Mork* (IMR) as an input to ASOF-N **WP1** and **WP2**. The earlier mentioned moorings M1 to M15 were deployed along the eastern slope of the Norwegian Sea, in the Greenland Sea and along its eastern edge. Potential temperature and salinity at the Gimsoy section were used to show the core of the AW flow in the area. Current meters in the eastern Norwegian Sea were deployed at the depths of 500m and 1000m. In areas of greater depths an additional instrument was placed in 2000m. The stability of currents, defined as a ratio between the mean vector velocity and mean speed of the current, indicated highly unstable flow in all locations except one mooring west of Sorkapp. Current stick plots and temperature time series were presented for selected moorings, confirming the strong meandering of the flow in the whole water column and significant variability of temperature in the AW layer. In the Greenland Sea the stability of the flow was much higher and temperature varied within a small range of ca 0.5°C. Wavelet spectra of temperature and current speed were presented for the southernmost location at the depth of 500m. The maxima representing the annual cycle and variability on monthly basis could be recognized. SSH anomalies from altimetry were presented for January 2005 and the average kinetic energy obtained from altimetry and measurements by the moored array was compared. The seasonal variations in the kinetic energy were observed with the largest values in the area near moorings M2 and M3. The positions of nine ARGO floats launched by IMR were presented adding up to 842 positions in total. The first three floats were deployed in 2002 and the highest speeds were observed during close circulation of the floats around the Lofoten Basin.

Øystein Skagseth (Bjerknes Centre) described the results from current measurements in the Barents Sea Opening (**WP2**). In addition to current measurements at moorings and hydrographic sections, the ADCP mooring results were presented. Annual means of current velocities from mooring showed the maximum value of ca 6 cm/s for the inflow in the upper layer in the eastern part and 4.3 cm/s for the bottom outflow in the western part together with the strong inclination of isopycnals, revealing a strong baroclinic component of the flow. Measurements by the bottom-mounted ADCP located at 70°40'N showed dominating M2 and S2 tides with maximum tidal current nearly 20 cm/s. Monthly averaged currents showed the strongest flow in winter period and the similar flow structure in the whole water column modified to some extent by the current shear. Progressive vector diagrams for different depths showed the mean flow in the north-eastern direction. The second bottom-mounted ADCP was located at the northern rim at 73°50'N and deployed for two one-year periods in 2003-04 and 2004-05. The dominating tidal components were M2, K1 and K2 and measured currents were stronger towards the bottom and directed mainly westward. TS diagrams were shown for two locations 78°30'N and 78°50'N with TS curves for 6 periods between 1989 and 2005. Significant differences between different periods were found in the northern part while in the second location only the period 1994-95 was outstanding. The AW inflow (defined as volume flux of water warmer than 3°C) and heat flux (relative T=0°C) estimated from measurements by the moored array were the highest in 1998 and early 2003 with two minima in 2000 and 2004. There is also an increase of the AW inflow observed in 2005. Correlations between the volume and heat flux and single point measurements were also analyzed with maximum value of 0.82 for the volume and 0.2 for the heat flux. A covariation of temperature and current velocity measured in the BSO with Svinøy and Fram Strait time series was found on the inter-annual time scale. A time lag for temperature is ca. 1.5 year while the lag in the velocity in the slope-current is small.

The results of **WP3** with the main focus on the variability of heat transport through Fram Strait were described by *Agnieszka Beszczynska-Möller* (AWI). The volume and heat fluxes through Fram Strait have been measured since 1997 by the array of moorings which during the ASOF-N period (from 2002 on) was significantly augmented with new instrumentation and adjusted to achieve the better performance. The complex structure of the AW recirculation in the deepest part of the strait was observed, revealing the topographically steered, meandering flow with bands of opposite, northward and southward cross-section current components reaching down to the bottom. Adding a level of instruments at the lower boundary of the AW layer improved heat flux estimates. The volume and heat fluxes measured through Fram Strait are characterised by strong month-to-month variability. The annual cycle is also present with the winter maximum in the heat transport. This seasonality results from the strong seasonal variations of the volume and heat transport in the WSC while in the recirculation area both fluxes vary on the shorter periods. The negative correlation was found between the volume flux in the WSC and recirculation area, indicating that a stronger recirculation can be linked with a decrease in the transport towards the Arctic Ocean. Based on the winter-centered annual means, the strongest increase of the heat flux was observed in 1997-99, when the amount of heat transported through Fram Strait nearly doubled. A slight decrease took place in 2000 and was followed in 2002-2003 by recovery of the heat flux to the maximum value from 1999. The next strong increase was found in 2004 and the heat flux has reminded significantly higher than average since then. Both increases of the heat flux were related to the warm anomalies propagating through Fram Strait but when during the first period the higher volume flux and higher temperature were equally responsible for the heat excess, in the last two years the significant warming of the AW was the dominant source of the observed change. In 2005 the warm anomaly spread westward, indicating the stronger recirculation of the AW in Fram Strait and/or a shift in the circulation pattern in the strait. The travel time of the warm anomalies advected from the North Atlantic to Fram Strait (between ca 63°N and 79°N) was estimated on ~1.5 years on the basis of measurements by moored arrays while estimates based on the model results suggested a slightly longer time lag of ca. 22 months.

After the lunch break *Kerstin Fieg* (AWI) presented the **WP3** results of the high resolution modelling of the exchange processes through Fram Strait. The MOM2-type model was used with 1/12° resolution in the Arctic (resolution of ca 8 km in Fram Strait), the boundary at 50°N and 50 vertical levels for the period 1990-2005. The initial conditions were taken from MOM2 1/4° run after 42 years of integration. The high resolution model used the NCEP/NCAR daily forcing and included also the freshwater input from main Arctic rivers, the Baltic Sea, the Bering Strait as well as Scandinavia and other rivers (Elbe/Weser, Rhein, Hudson). A comparison between the low (1/4°) and high (1/12°) resolution model results was presented as well as the preliminary comparison of modelled and measured fluxes. The annual mean streamfunction field in Fram Strait showed the more complex flow, stronger in the deep part and weaker over the Greenland shelf reproduced by the high resolution model. The volume and heat fluxes through Fram Strait are comparable for model and measurements estimates but the recirculation patterns are more pronounced in model results. Temperature distribution at the depth of 300m in May 2000 obtained from the high resolution model showed a well-reproduced flow of the warm AW in the WSC along the slope and its strong recirculation north of the strait which were not visible in the low resolution modelled field. For the northward and southward volume fluxes the mean values from the high resolution model and mooring measurements match well with much stronger month-to-month variability in the observations. For the northward and southward heat fluxes the measured values are between the 1/4° and 1/12° model results but both peaks in the heat flux observed in 1999 and 2004 are well reproduced by the high resolution model. For the heat flux the modelled and observed values are of the same order of magnitude and the variability of the net heat flux is also comparable in the model result and observations. But the comparison or identification of the single observed structure or event in the modelled fields is still difficult. A comparison of the freshwater content and ice volume in the Arctic in 1995-2003 showed similar values for both models with slightly more ice reproduced by the high resolution simulation and more freshwater in the low resolution one. The freshwater transport through Fram Strait is bigger in the low resolution model. The salt transport through Fram Strait in the 1/12° model is ca half of the value obtained from the 1/4° model and the Arctic is gaining salt in both models. The conclusion is that the integrated quantities are little affected by resolution what leads to the realistic long mean climate state obtained from both models while the local conditions deviate substantially due to the model resolution and high resolution model gives the better representation of the small scale variability.

The next series of talks was focused on the freshwater transport through Fram Strait and included results achieved in **WP4**. The summary of the Fram Strait freshwater flux activities was given by Edmond Hansen (NPI). The ASOF-N observational array for freshwater measurements was redeployed in 2003, 2004 and 2005 with the main challenge to measure temperature and salinity in the upper 40-80 m. The tube moorings have been also used for measurements on the shelf since 2003. Annual cruises provided the high resolution distribution of temperature and salinity but only in the summer. The first winter cruise in May 2005 provided the winter stratification. The liquid freshwater transport in the East Greenland Current (EGC) was estimated for 1997-2004 with the annual average ca 1000 km^3/y and its annual cycle was recognized with the minimum in April and maximum in September. Observations of the freshwater flux were compared with the NAOSIM model results, revealing a good agreement between the monthly observed and modelled values for the section covered by measurements. The ULS algorithms are worked on to improve the open water detection algorithms together with a requisite *in situ* verification. During the winter cruise in May 2005 ice thickness measurements were performed in Fram Strait, including ground electromagnetics and snow depth measurements, airborne electromagnetic profiling, drillings and measurements by upward looking sonars. A serious problem occurs by losses of moorings and instruments due to the increased activity of icebergs. The future work will include the updated sea ice flux, now estimated on the 2200 km^3/y on the annual mean, and observations of the freshwater flux on the Greenland shelf.

The detailed description of the freshwater flux and its variability (**WP4**) was given by *Jürgen Holfort* (NPI). The methodology used for the freshwater flux estimations included mooring data, hydrographic sections, climatologies and different spatial interpolations. Time series of the liquid freshwater transport were calculated using the corrected climatology with time dependent near surface values, salinity measured in summer 2003 at the hydrographic section and the WOA01 climatology. Significant differences were found for the latter due to the imperfection of the climatological temperatures and salinities in the near-surface layer for the western Fram Strait. A comparison between different available climatologies (WOA 1°, WOA ¼°, PHC 1° and WOCE) was also presented for the studied area. Calculations using different spatial interpolations and/or reduced datasets showed that interpolation does not influence the estimated transport in a significant way but a horizontal gap in the data (due to lost moorings) results in the serious error. The mean seasonal cycle was pronounced in the volume and freshwater fluxes with a common spring minimum (March for volume and April for freshwater). The volume flux has a maximum in late spring/summer while the strongest freshwater flux is delayed until September due to melting processes. The freshwater transport estimated from mooring measurements was compared with the calculated geostrophic transport based on hydrographic sections and related to the bottom. In general there was a good agreement between the transports based on moorings with the transports from hydrography and model. The freshwater flux revealed minima in 1999 and 2004 and two maxima within the period 2000-2002. The freshwater flux is closely correlated with the volume flux of the low salinity water ($S<34.5$). The long term mean freshwater flux was estimated on ~1000 km^3/year while the longer term variations are of the order 500 km^3/year and no trend is visible. The largest uncertainties are due to the unknown transport on the shelf east of 7.5°W.

In addition to **WP4** results the recent changes observed at the 74°N section by the German SFB 514 were presented by *John Mortensen* (IfM Hamburg). The salinity section along 74°N, measured in September/October 2005 illustrated a distribution of different water masses. Significant differences were found in TS characteristics of the Polar Surface Water (PSW) and Greenland Sea-Arctic Surface Water between 2002, 2004 and 2005 with a shift towards higher salinities. It was confirmed by the volumetric analysis which showed an increase of the volumetric thickness within the higher salinity range. The temperature and salinity time series measured by tube moorings located at 63°N and 74° were presented. A high correlation between the tube mooring inclination (pressure) and current velocity measured by ADCP was found. The cumulative freshwater transport at 74°N was estimated on 1100÷2000 km^3/year.

Two next presentations were given by *Svein Østerhus* (UiB). In the first one he described the historical measurements in the East Greenland Currents in Fram Strait dome in 1984-2000. Between 1984 and 1996 from one to nine instruments were deployed on a yearly basis (7 deployments) in the EGC by a joint effort of GFI and NPI. In 1997-2000 from 4 to 6 moorings were deployed in the frame of the VEINS project. Examples of monthly mean velocity fields were shown for 2000 and a method for the transport calculations was explained. The mean southward volume transport for 1984-85 versus 1998-2000 was estimated as 2.3 Sv in the earlier period and 2.2 Sv in the later one. The Polar Water volume transport was estimated as 1 Sv and 1.4 Sv respectively. In summary during most of the 1984-2000 period the data coverage was too sparse to draw any reliable conclusions. But the larger fraction of Polar Water in the late 90's suggests possibly the larger freshwater transport. In the following talk *Østerhus* described the status and some scientific results of the **MOEN (ASOF-EC-E)** project. Three main branches of the warm and saline AW flux were investigated in the project: the Iceland Branch/Irminger Current west of Iceland, the Faroe Branch/Current over the Iceland-Faroe Ridge and the Shetland Branch, Continental Slope Current through the Faroe-Shetland Channel. The total Atlantic inflow for the period January 1999 to December 2001 was estimated as 8.5 Sv on average with minimum of 8.3 Sv and maximum of 8.7 Sv. The related heat flux was on average 313 TW and the salt flux 303 kT/s. The amplitude of the seasonal variations was 0.4 Sv with the maximum AW inflow in October. The Atlantic inflow was divided among three branches as following: the Shetland Branch 4.2 Sv, the Iceland Branch 0.8 Sv and the Faroe Branch 3.6 Sv. There was no significant covariance found between the Iceland and Shetland branches. The modelled time series of the AW inflow for all branches for 1950-2005 were compared with estimates based on measurements. The modelled mean AW inflow was 8.7 Sv. The revised scheme of volume fluxes was presented as the final result of the MOEN project. The final report will be due in the end of January 2006. The observations are planned to continue as the effort by national programs and under the IPY umbrella. The short separate presentation on the modelling activities in the MOEN was shown by *Østerhus* on the behalf of *Steffen Olsen* (DMI). The main goal was to produce hindcasts for the period 1948 to present of the Meridional Overturning Exchanges with the Nordic Seas, assess the role of initial conditions using an ensemble approach and to quantify the impact of increasing Arctic river discharges on modelled exchanges and watermass composition. The modelling strategy was explained and the centennial variability of the control simulation was presented. Five different sections were chosen for flux calculations: Fram Strait, Barents Sea Opening, Denmark Strait, Iceland-Scotland section, Labrador Sea section; all sections with Atlantic waters (AW) , EGC waters (EGC) and overflow waters (OW) defined by different T and S boundary values. Within the ASOF-N area of interest the ensemble means for the period 1948-2005 were: for the Fram Strait section 1.3 Sv of AW, 1.9 Sv of OW and 1.4 Sv of EGC, for the Barents Sea Opening 2.2 Sv of AW and 0.4 Sv of OW. There was a good agreement for the AW inflows in three branches monitored in the MOEN between the mean measured and modelled values.

The last Thursday talk was given by *Bob Dickson* (CEFAS) who reported on the status and results of the **ASOF-EC-W** project. He described the development of freshwater flux and overflow arrays off SE Greenland. The expectation is that the two dense overflows that drive the MOC will weaken or/and that the freshwater outflows from the Arctic Ocean to the North Atlantic will strengthen determined the field site. CEFAS has measured the Denmark Strait overflow since its first measurement in 1986, latterly with UHH & FIMR. In 2000, they extended west to cover the freshwater flux passing south on the SE Greenland shelf. The array deployed in 2004 consisted of 7 standard moorings, two tube moorings, two bottom-mounted ADCPs and one bottom-mounted water sampler. The tube moorings were designed to withstand an impact from the drift ice and until 2004 they have been reasonably successful when the huge amount of grounded icebergs appeared in the area. Remote sensing used to measure the recent changes in mass balance and velocity of Greenland glaciers revealed that the sustained acceleration of southeast Greenland glaciers combined for the largest mass loss in Greenland: 120 cubic km/yr ice loss in 2005 from ice dynamics. Though providing only partial coverage in its present form, the freshwater flux array off SE Greenland has been used to provide a first estimate (64 mSv) for the flux (relative to S = 34.8) along the outer part of the SE Greenland shelf. The Denmark Strait overflow array covers most of the overflow (8 Sv) while the external part of the overflow was estimated on 2.7 Sv giving the total of 10.7 Sv. A thickness of the dense layer ($\sigma_\Theta > 27.8$) is closely correlated with a bottom depth. Estimates of overflow transport were given, based on different combination of moorings and the mean transport for the short period with the full set of moorings (1998/99 and 2001/02) was estimated as 7.3± 0.9 Sv. For the standard array, the mean speed and depth of 27.80 and 27.85 isopycnals were shown for the long period (1986-2005) and last decade (1996-2005). Over the 8–9 year period for which the records of flow are continuous (1997-2005), the dense-water transport estimates showed no significant trend. The geostrophic transports of water with $\sigma_\Theta > 27.8$ and $\sigma_\Theta > 27.85$ based on hydrographic sections in 1997-2005 were in the range of estimates from moorings. On the other hand the overflow transport across the Denmark Strait Sill measured in 1999-2003 by 3 ADCP (Macrander et al., 2005) showed significant decreasing trend. *Dickson* compared transport time series from ADCPs and from the ASOF-W long term conventional current meter array and found that the observed decrease was present only in the short period of ADCPs measurements. The temperatures since 1986 in the bottom 100m at mooring set at 2000m water-depth in the core of the Denmark Strait Overflow on the SE Greenland Slope off Angmagssalik are the evidence of decadal fluctuations in overflow temperature. Time-series of salinity from near-bottom depths in the core of the Denmark Strait Overflow show freshening in the early part of most years (local forcing?) and extreme freshening by up to 0.1 in January to July 2004. The 2004 freshening occupied the full width of the overflow. The attempt to track the dominant temperature and salinity signals downstream from the Denmark Strait Overflow Array off Angmagssalik in sites around and in the Labrador Sea was made in collaborative work with Igor Yashayaev, BIO and some indications of a recent decrease in DSOW density were found. A contribution of the overflows to the changing volumetric census of the Labrador Sea Basin was also shown to depict the recent shifts in the dominance of salinity classes vs time. The areas of origin of the overflow is also still an open question and a new path for the Denmark Strait overflow was found at the Hornbanki section north of Iceland. The future plans for both arrays include for the freshwater flux array the redeployment with one tube mooring and ADCP (seeking to replace a second tube mooring) and for the overflow array a replacement without additional cost. Additional information on the ASOF-W activities was given by *Jens Meincke* (IfM Hamburg). He presented results of hydrographic sections between 60° and 65°N with a focus on the temperature and salinity variations in 1997-2005.

The second day of the ASOF-N seminar was started with the presentation focused on data management and the project website (**WP5**) given by *Gerd Rohardt* (AWI). He described the latest updates and changes on the project webpage. Regarding the data management it was stressed that all partners are requested to send information about the current status of the cruises including: a cruise report, CTD station list, mooring recovery and/or deployment summaries, summary of other used instruments (e.g. VM-ADCP, floats), cruise and station maps and instruments details. Two new features were added to the webpage in the data management part allowing to show the current contents of the database and a map of all CTD stations and mooring locations. The ASOF-N expeditions page still has a lot of gaps for 2005 due to missing reports. The new column was added in the expeditions table with the data base cruise name which depict that dataset from the cruise can be retrieved from the database. A database explorer was presented on-line using the example of the AWI CTDs and moorings from 2005. Some important issues of the data processing (standard routines, despiking, correction for declination for RCMs, averaging, etc.) were discussed as well as the problem how to treat data from additional instruments, which are used at arrays outside the ASOF-N scope (not paid by project). The request for delivery of all project data was strongly stressed because the time required for the preparation the ASOF-N data CD which is due in the end of the project (March 2006).

The synthesis of the ASOF-N (**WP6**) was addressed by *Bert Rudels* (FIMR) who described results of the Oden–Healy transpolar cruise in 2005 and discussed some implications for the ASOF–N observations. Temperature and salinity profiles as well as TS-diagrams were shown for the Eurasian Basin to compare 1994 and 2005 and for the Canadian basin to compare 1994, 1997 and 2005. The formation areas and circulation schemes for the Fram Strait and the Barents Sea branch contributions to the "lower" halocline were presented. The example of mass balance including the inflow of 1 Sv for Fram Strait, 2 Sv for the Barents Sea Opening and 0.8 Sv (plus 0.2 Sv of freshwater) for Bering Strait and the outflow of 1.5 Sv via the Canadian Arctic Archipelago would have to lead to the significant sea level increase in the Arctic Ocean. This suggests a need to compare and integrate time series of volume transports across the Svinøy, the Barents Sea Opening and Fram Strait to refine and verify the mass transport. The presented freshwater balance with a net inflow of 1 Sv through Fram Strait would include: the inflow of Atlantic water through Barents Sea 2 Sv with salinity 35.0, the inflow of Pacific water through Bering Strait 0.8 Sv with salinity 32.5, the net inflow of 1 Sv through Fram Strait with salinity 35.0, the outflow of 1 Sv of Polar water with salinity 33.5 through Fram Strait. The salinity of the outflow through the Canadian Arctic Archipelago is assumed to be 33.2. The balance can only be transient because it requires that the outflow of Polar surface water must be increased by 100% which would reduce its thickness by half in 5 years or 0.12 Sv of ice has to be used to dilute the Atlantic water. This means that the ice thickness in the Arctic Ocean would be reduced by half after 3 years. If it should be a stable situation, the total liquid freshwater export, excluding the Pacific inflow, must be 0.24 Sv (ice export is about 0.08 Sv). The freshwater input is about 0.1 Sv (river runoff) + 0.07 Sv (net precipitation) thus 0.7 Sv would be missing. Another view on the freshwater balance assumes the outflow through Fram Strait 0.09 Sv as ice and 0.03 Sv as liquid water, the input as river runoff of 0.09 Sv, the input as net precipitation of 0.07 Sv, the inflow through the Bering Strait (relative to salinity 35.0) of 0.06 Sv and the export through the Canadian Arctic Archipelago of 0.1 Sv with salinity 33.2. This balance requires a net outflow of 1.95 Sv to keep the mass balance.

A comparison of the TS-diagrams in the Eurasian and Canadian Basins shows some changes in the Atlantic and intermediate layers. A scheme of the intermediate water circulation and the two Atlantic inflows in the Arctic Ocean was proposed. On this basis two warm inflows of the Atlantic water in the late 1980s and in the mid 1990s were tracked in the interior of the Arctic Ocean. The changes of temperature and salinity distributions in Fram Strait between 1984 and 1997 illustrated the first inflow. Time series of the mean temperature and salinity in the upper 50-500m from hydrographic sections in Fram Strait also show these warm and saline anomalies traveling into the Arctic Ocean. Regarding the 1990s anomaly and a warm AW inflow observed in Fram Strait in 2004-2005 the question arises about the changes to be expected in the Arctic Ocean in next years. The distribution of different warm pulses of Atlantic water in the Arctic Ocean in 2005 was schematically presented. A distinct inflow pulse of warm Atlantic water becomes spread out around the Arctic Ocean basins, which complicates the formulation of a heat balance for the Arctic Ocean. There are new questions involved: how much is lost to the other water masses, how much to the melting of ice and to the atmosphere, how much is re-exported through Fram Strait. Temperature and a salinity of deep and bottom waters in the Makarov, Canada, Amundsen and Nansen Basins which are higher when compared to those in the Greenland Sea imply that deep and bottom waters are renewed within the Arctic Ocean. The only process that can accomplish this is brine rejection on the shelves and the subsequent sinking of dense, saline entraining plumes down the continental slope. This process leads to an increase in both salinity and temperature towards the bottom. The Makarov Basin bottom water is different. Here the temperature decreases towards the bottom. A spill-over across the Lomonosov Ridge is a possible, but not proved, explanation. The increase in temperature towards the bottom could also be due to geothermal heating, leading to a deep isothermal, weakly stirred bottom layer. A circulation scheme for the deep waters of the Arctic Mediterranean was also proposed. The gap in the Lomonsov Ridge was measured during the 2005 transpolar cruise. The Oden observations from the Beringia-05 expedition did not confirm any flow of Amundsen Basin deep (2300m) water into the Makarov Basin. On the contrary it indicated a strong flow of Canadian Basin deep water into the Amundsen Basin located around 1900 m. The general question was whether there is more and more 'noise' in all measurements, including presence of eddies and spatial and temporal variability. The main focus should be put on how the water masses are transformed in TS space because this is needed to determine the part of the transports that are relevant for the climate. How do the TS characteristics change as the Atlantic and intermediate waters make their loops in the Arctic Ocean is the main issue which should be addressed. In this context Fram Strait is the key passage.

The last presentation given by *Rebecca Ludwig* (EMPA) was devoted to the details of the **Technical Implementation Plan** (**TIP**). The European Commission uses the TIP for three main goals: to report on the success of its programmes, to communicate results to a wider world and to demonstrate exploitation from FP 5. The TIP is a contractual document and it structures the exploitation and identifies the future research and development needs (e.g. for next proposals). The CORDIS webpage prepared for the electronic submission of the TIP components was described and recommended to ASOF-N partners. The short training on how to access all available research results was given to show the examples from other projects. Ten main results have been identified for ASOF-N. They are divided into three main groups: basic data (CTD data, mooring data, floats data), derived properties including modelling results (Atlantic water pathways, fluxes across the western Barents Sea, heat flux through Fram Strait, freshwater flux through Fram Strait) and integration and synthesis (system diagnosis, optimized observing system, advice to managers). The responsible persons and partners owing different results were indicated. A structure of the part 2 of the TIP which describes the individual results was discussed in details. It includes documentation and information, intelectual property rights, descriptors for the market application sectors, quantified data on additional partners, targeted user audience and referenced publications, potential offered for future dissemination and use and profile of additional partners. The ASOF-N results and their description were discussed in this context. Exploitation plans for individual results were also debated. The present status of the eTIP website for ASOF-N project was presented on-line with the indication where an input from the project partners is still necessary. All information on the TIP and required input can be obtained directly from EMPA.

A presentation on referring to the way towards FP7 prepared by *Johanna Wesnigk* (EMPA) was distributed as a paper copy.

The short discussion on the preparing the final report and deliverables due until the end of the project followed next. Coordinator of ASOF-N project, *Eberhard Fahrbach* reminded that the earlier input from all partners is strongly required to meet the deadline for the final report. An intended structure of the final documentation was also briefly discussed with a special focus on Section 3 consisting f the detailed report organized by work packages including data on individual contributions from each partner and Section 6 including the detailed report related to overall project duration to be written by coordinator on the basis of inputs from all project partners.

The 3rd ASOF-N seminar in Bremerhaven was closed by Fahrbach who gave all project partners his full acknowledgement for their efforts in keeping the ASOF-N on the highest level, regardless of demanding and far-going objectives, intensive commitments and many technical difficulties of the field work in the harsh Arctic environment.

Appendix 1

List of participants of the 3rd ASOF-N seminar in Bremerhaven, 8-9 December 2005

Name	Institution	e-mail
Agnieszka Beszczynska-Möller	AWI	abeszczynska@awi-bemerhaven.de
Bob Dickson	CEFAS	r.r.dickson@cefas.co.uk
Eberhard Fahrbach	AWI	efahrbach@awi-bemerhaven.de
Kerstin Fieg	AWI	kfieg@awi-bemerhaven.de
Jean-Claude Gascard	LODYC	Jean-Claude.Gascard@lodyc.jussieu.fr
Rüdiger Gerdes	AWI	rgerdes@awi-bemerhaven.de
Edmond Hansen	NPI	edmond.hansen@npolar.no
Jürgen Holfort	NPI	juergen.holfort@npolar.no
Cornelia Köberle	AWI	ckoeberle@awi-bemerhaven.de
Harald Loeng	IMR	harald.loeng@imr.no
Rebecca Ludwig	EMPA	r.ludwig@empa-bremen.de
Jens Meincke	IfM Hamburg	meincke@ifm.uni-hamburg.de
Kjell Arne Mork	IMR	kjell.arne.mork@imr.no
John Mortensen	IfM Hamburg	mortense@ifm.uni-hamburg.de
Svein Østerhus	UiB	svein.osterhus@gfi.uib.no
Jan Piechura	IOPAN	piechura@iopan.gda.pl
Gerd Rohardt	AWI	grohardt@awi-bemerhaven.de
Bert Rudels	FIMR	Bert.Rudels@fimr.fi
Ursula Schauer	AWI	uschauer@awi-bemerhaven.de
Øystein Skagseth	Bjerknes Centre	oystein.skagseth@imr.no
Waldemar Walczowski	IOPAN	walczows@iopan.gda.pl
Johanna Wesnigk	EMPA	j.wesnigk@web.de