ASOF-N

Arctic-Subarctic Ocean Flux Array for European Climate: North

REPORT

of the 2nd ASOF-N Seminar

6-7 December 2004

Bremerhaven, Germany

The seminar was opened on Monday, December 6, with a short welcome by the Coordinator of ASOF-N project, *Eberhard Fahrbach.* First the updated agenda was discussed with necessary changes due to the absence of Bob Dickson and Svein Østerhus. A list of participants can be found in Appendix 1. Next, a brief overview on the overall objectives of the ASOF-N project and its particular workpackages and tasks was presented by *Fahrbach*. The updated Gantt chart, demonstrating the progress of the project was reviewed in details. All deliverables split between the workpackages were listed with a special attention paid to those required in the near future. The obtained and approaching milestones of all workpackages were also discussed and summarized. The issue of information and data flow to the project data center was emphasized as a part of the required deliverables. A full list of deliverables and milestones can be found in Appendix 2.

After the introduction the scientific part of seminar started with a talk given by *Waldemar Walczowski* (IOPAS) on the volume and heat transports measured by a ship-mounted ADCP, lowered ADCP and calculated from hydrography in the **WP1** area. He presented the results from r.v. 'Oceania' cruise in summer 2004, comprising hydrographic measurements along twelve sections between Norway and the north tip of Svalbard. As compared with the previous year, the horizontal distribution of temperature shows wider and warmer flow of the Atlantic water in the eastern Fram Strait. There is general agreement between the LADCP measured and baroclinic AW pathways but total transports calculated using LADCP data are much higher then those obtained from the baroclinic calculations. The convergence of two AW streams was observed at ~78°N. Series of repeated measurements at the section at 78°50'N revealed high temporal variability of volume and heat transport while the flux of AW was much more stable.

Jean-Claude Gascard (LODYC) continued the presentation of **WP1** results with a talk on the Atlantic Water pathways based on the lagrangian observations in the Lofoten Basin combined with hydrological data. During the ASOF-N period *ca* 60 floats were deployed in three series and, as opposite to earlier MAIA floats partly found in Fram Strait, all of them were advected with the Barents Sea branch of the NAC. A coherent large-scale anticyclone was observed between November 2003 and January 2004 in the region where the NAC splits into the Barents Sea and Fram Strait branches. The vertically integrated transport in the upper 600m was estimated on *ca* 3 Sv. Slowing down the floats propagation due to the large-scale eddies may possibly cause a time delay of more than 6 months, preventing the floats to reach Fram Strait within the observation period. The temperature and salinity of AW at both Bjørnøya and Gimsøy sections observed in 2003 and 2004 were higher as compared to 2000 together with an increase in the layer thickness. However, the baroclinic volume transport in the upper 700 m was decreased in both cases. In 2004 the LADCP measured transport at the Gimsøy section was estimated on 8.2 Sv in the NAC with additional 1.2 Sv carried on by the NCC. The total volume transport at the Bjørnøya section amounted 3.4 Sv.

The results of current measurements in the Norwegian Sea (**WP2**) by means of profiling ARGO floats were shown by *Kjell Arne Mork* (IMR). 9 of 17 active floats in the Nordic Seas were deployed by IMR in 2002 and 2003 in the frame of ASOF-N. Most of them went around the Norwegian and Lofoten Basins, registering the vertical distribution of temperature and salinity along their tracks. The mean speed of floats going around the Lofoten Basin was in the range of 5.5-6.5 cm/s while for the Norwegian Basin it was lower (*ca* 3 cm/s). Annual sea surface height variability in the Nordic Seas was also presented on the basis of the altimetry and hydrographic data. Similar patterns in the horizontal distribution of amplitude and annual phase of alimeter data and steric height from hydrography were found, especially along the eastern boundary of the area. The seasonal distributions of anomalous bottom currents relative to the annual mean also showed a winter/summer reversal in the boundary current and a spring/autumn reversal in the gyre. Future work to estimate the geostrophic transport at the

Svinøy section back to 1992 was proposed with the use of combined altimetry and hydrography data to find the reference/bottom velocity.

In the next talk *Randi Ingvaldsen* (IMR, Bjerknes Center) continued to present **WP2** results, focusing on the measurements between Norway and Bear Island. Positive anomalies of temperature and salinity have been observed since 1998 and the high temperature anomaly was found to be in phase with the increased area of the AW at section. This suggests that the lateral extent of the NAC in the Barents Sea increases in warm periods. The mean flow pattern may have one or two cores of Atlantic inflow with two cores most pronounced when the temperature is high. The interannual variability in the observed AW volume flux was strong. The strongest inflow found in 2002 and 2003 as compared to the rest of the time series was followed by a decrease of the volume flux in 2004. The volume flux and the temperature of the inflowing AW were found to be only weakly correlated.

The coherent and lagged signals in the Norwegian Atlantic Current from the mooring records were presented by *Øystein Skagseth* of Bjerknes Centre. The coherent changes in the NAC were found with a high correlation between leading modes of the surface current from satellite sea surface heights and sea level pressure. The large scale wind driven variations dominate on the shorter time scales. The annual running means of simultaneous temperature and current velocity records from the Svinøy section and downstream in the Barents Sea Opening and West Spitsbergen Current were calculated to get homogeneous time series. A coherence between the measured and based on altimeter data along-slope current in the WSC was found for 1-2 months period as well for interannual variability. Interannual variation of temperature revealed a delay of *ca* 2 years between the Svinøy section and BSO and of *ca* 1.5 years between the former one and WSC. For current velocity there is a connection between the Svinøy section and BSO while in the WSC the situation is complicate because of the cross-current structure of the variations. The altimeter SSH data can be used as independent observations for reference and check.

The ASOF-EC-W status was reviewed by *Jens Meincke* (IfM). Arrays of moorings east of Greenland are operated by CEFAS, IfM and FIRM in the frame of the ASOF. Time series of the dense overflow were presented for 1997-2003. Freshwater fluxes are measured farther to the north by the ADCP located between two tube moorings. The importance of the heat fluxes between ocean and atmosphere with maximum in winter was stressed as a possible source to enhance the energy of atmospheric lows. A focussed field experiment is planned for 2005 in the Lofoten Basin with research vessels and aircraft, drifting automatic buoys and satellite remote sensing.

Karin Latarius (CMAS) presented a talk on the preliminary heat and freshwater budget of the Greenland Sea Gyre. Seasonal changes in the hydrographic properties in the Greenland Sea were measured in the layer 0-2000m by ARGO floats between March 2001 and January 2003. While there are significant differences in the seasonal heat content based on NCAR data and those from ARGO floats for the first year of measurements, the heat fluxes reveal similar seasonal variability. However the heat fluxes variability on monthly time scales estimated from ARGO floats suggests a strong heat input to the Greenland Sea Gyre through the eddy fluxes. The heat transport necessary to balance a loss to the atmosphere requires ca 2 Sv of advection. The freshwater balance of the Greenland Sea includes the main input during summer and the vertical redistribution of freshwater through convection in winter. The balance of the freshwater transport requires *ca* 3 Sv of advection what again suggests the strong input to the Greenland Sea through eddy fluxes. Air-sea fluxes account for about half of the heat content variability and horizontal eddy fluxes provide the rest of the heat flux as well as all of the freshwater flux.

After the coffee break the status of modelling efforts in **WP3** was described by *Kerstin Fieg* of AWI. A task of combining the observations and model results to understand the mechanisms which control variability of fluxes in Fram Strait needs the complete Arctic domain to be included in the model. On the other hand the task of finding the critical locations for the optimal observation array design requires a resolution comparable to measurements. The numerical model developed in AWI is based on MOM-2 with 1/12° resolution in the Arctic starting from the 50°N. It gives ca. 8 km resolution in Fram Strait with 50 vertical levels. Topography is based on ETOPO5 and boundary conditions on NCEP/NCAR daily forcings. The initial conditions come form MOM-2 1/4° model run after 42 years of integration time. A spin-up time of the high resolution model is expected to be at least 5 years. A comparison of snapshots from 1/12° and 1/4° models reveals intensive mesoscale structures with the numerous eddies and strong meandering along the main pathway of the Atlantic water which are not resolved by the low resolution model. After finishing a standard model run, the analysis will focus on the model variability and its comparison with the observed changes. A sensitivity experiment run with use of the ERA 40 forcing data from ECMWF is also intended to improve a model performance.

Results from observations by the mooring array in Fram Strait in 1997-2004 were presented by *Agnieszka Beszczynska-Möller* (AWI) as a part of **WP3**. The main attention was paid to a strong intra- and interannual variability of the volume and heat fluxes through Fram Strait. The measurements by a mooring array have been carried on since 1997 while with the start of ASOF-N the array was augmented with two new moorings and an additional level of instruments. The array is operated in the cooperation with NPI. Results obtained with the extended mooring array revealed a strong multistream flow system in the recirculation area which had not been resolved by earlier measurements. The mesoscale eddies over the West Spitsbergen slope and in the central part of Fram Strait are another source of uncertainty for the estimation of heat and volume fluxes. Using the monthly means should eliminate this problem to some extent thus the preliminary estimates of volume and heat fluxes are based on monthly averaged data. The net volume transport to the south was found except for the period 2001-2003 with net northward annual flux of 0.4 and 0.6 Sv respectively. The strongest increase of the heat flux was found during two first years (1997-2000) with a slight decline in 2000/2001 and restoring to the high value in next years. The maximum annual average of the heat flux was observed during the last year of measurements. Thus for the ASOF-N period (2002-2004) a detailed analysis with use of daily means was performed. The mesoscale disturbances were removed by low pass filtering of temperature and current data. The EOF analysis of temperature revealed a dominating first mode with the seasonal signal and a maximum between August and October and a second mode with a seasonality pattern in the AW layer showing the maximum between October and December. The first EOF modes of the cross-section currents in the EGC and WSC revealed variability dominated by monthly time scales. Most of the variability in the net volume transport through Fram Strait was found to be generated by the variability in the recirculation area in the central part of the strait, which is responsible for ca 50% of variance of the net volume flux. However, most of variance in the net heat flux through Fram Strait is explained by its variability within the WSC. The strong seasonal variability is observed in the volume flux of AW with T>3° with a maximum and the largest spatial extent in winter. The strong increase of the heat flux in 2003/2004 resulted from the much stronger than average northward transport of warmer than average Atlantic water during the late spring and summer of 2004. A strong correlation was found between the volume flux in the WSC and zonal and meridional atmospheric pressure gradients over the Fram Strait area. The net volume transport through the entire strait was significantly correlated with the north-south component of the wind stress in the western part of Fram Strait. Future work will include a comparison of the Fram Strait fluxes with those available from the Svinøy section and BSO as well as analysis of PIES and bottom pressure recorders time series with a special focus on optimizing the mooring array. The next redeployment of the ASOF-N mooring array will take place in summer 2005.

In a frame of **WP3** results *Sergey Pisarev* (Shirshov IORAS) presented an analysis of the interannual variability of AW flowing through Fram Strait based on the reconstruction from historical observed data. He stressed the fact that the available reconstructions of the AW variability in the Arctic Basin differ significantly even when based on the same data set. Also strong differences are found for the reconstructions of the AW variability in Fram Strait, dependent mostly on a definition of the studied area. Pisarev proposed another reconstruction for the region north of 79.5°N based on more than 3000 stations and two definitions of AW depending on latitude. The analysis included data from the layer 150-300m. The influence of the seasonal variability was reduced by dividing the time series into four seasons. The variability of the AW temperature in last 100 years was presented for different locations.

Edmond Hansen (NPI) talked on the results of **WP4**. The fresh water flux through Fram Strait was measured by an array of moorings equipped with ULSs, tube moorings and ADCPs. The mooring array was redeployed in 2004 and a number of CTD sections was performed in Fram Strait. The collected data were processed and calibrated to estimate the liquid fresh water flux mainly on the East Greenland shelf. The performance of ULS was also evaluated on the basis of data sets collected before and during ASOF-N. ULS algorithms refinement is crucial to distinguish the physical signal from a noise in the extremely dynamic area east of Greenland, dominated by divergence (open water) and convergence (ridging) areas, influenced by polar lows and local storms and with strong tidal and topografic effects. The accuracy of ice thickness estimates depend on the open water detection (reference level). The open water fraction should contain a strong seasonal signal which can be used as a test of the algorithm performance. A strong seasonal signal should be also present in the average thickness with a maximum in summer. The average annual cycle of ULS measured data reveals a maximum of ice thickness in July-August. The future work will include completing the liquid fresh water time series and calculating the solid fresh water flux (ice) until 2004. Two cruises are planned in April and September 2005, including winter hydrography with AXCTDs. The liquid fresh water fluxes will be compared with those measured at 74°N (in cooperation with IfM Hamburg) and with numerical models results.

Detailed estimates of the liquid fresh water fluxes thorough Fram Strait at 79°N were presented by *Jürgen Holfort* of NPI as a result of **WP4**. During the ASOF-N period they were measured by moorings in the East Greenland Current above the continental shelf break and on the shelf. Estimates of fresh water flux on a basis of WOA salinities and with use of summer salinities measured at moorings were compared, showing that the former ones resulted in a strong underestimation of the calculated fresh water flux. First time series of temperature and salinity at the East Greenland shelf could be measured due to deployment of the tube moorings which are able to operate in the subsurface layer even under the ice. First processing of ADCP data was also done, showing a strong tidal signal and small mean southward velocities with hints to a larger seasonal signal. More advanced tube moorings were deployed in 2004. In future a thorough checking of topographical features in the vicinity of ADCP locations is intended as well as detidying the ADCP data. ADCP data will be combined with the tube mooring measurements to get the fresh water flux estimate.

John Mortensen (IfM) showed the results of SFB512 cruise to the Greenland Sea and East Greenland Current as a continuation of **WP4** works. Two CTD sections were measured at 74°N and 74°30'N across the East Greenland shelf and western Fram Strait. The tube moorings were redeployed in the East Greenland Current at 63°N, 74°N and in Fram Strait. The distribution of water masses at the section was presented as well as TS diagrams for CTD stations measured in 2004 and data obtained by the tube moorings.

Marika Marnela (FIRM) presented the exchanges of SF_6 between the Nordic Seas and the Arctic Ocean based on the experiment performed in 1996 when 320 kg SF_6 was dumped in the Greenland Sea Gyre at the density level of 1028.049 kg/m^3. Concentrations of SF_6 were measured during the r.v. 'Oden' cruise in May 2002 and r.v. 'Knorr' cruise in July 2002. Geostrophic velocities at the three 'Oden' sections and one 'Knorr' section were calculated. A classification of water masses based on the potential density σ_θ and potential temperature was used, distinguishing the surface water, Atlantic water, dense Atlantic water, intermediate water and two types of deep water. Maximum concentrations of SF_6 were found in the intermediate water layer at the Oden eastern section.

The results of **WP6** including the integration and synthesis were presented by *Bert Rudels* (FIRM). He stressed a fact that the estimates of the fluxes through Fram Strait and across the Barents Sea must be coordinated. His estimates show that 1 Sv of imbalance during 1 day implies 1 cm sea level rise of the Arctic Ocean, 1 month of 25-30 cm, 1 year results in 3 m sea level rise. A compensating outflow can only occur through the Canadian Arctic Archipelago and then involve mainly the less saline Pacific water and water from the Barents Sea branch halocline. This would have profound effects on the stratification in the Arctic Ocean. Reference salinity and temperature to use when establishing heat and freshwater transports have to be re-examined. He suggested to use the mean salinity of the inflowing water together with the mean temperature of the outflowing water and showing the freshwater and heat fluxes together with the total outflowing volume and the inflow salinity and the total inflowing volume and the outflow temperature. Possible effects of the volume imbalance should be indicated. The heat transport relative to the outflow temperature based on geostrophic calculations from CTD sections in 1980-2004 was presented together with fresh water transport relative to the inflow salinity. Properties of the Atlantic water west and north of Svalbard were compared. Cooling and freshening of the Atlantic water also in the deep layers indicate the injection of less saline and cold (freezing point) shelf water. This implies that about the same amount of shelf water as Atlantic water is entering the Arctic Ocean in the 'Svalbard' stream. Still there is a question about the possible recirculating around Svalbard in the East Spitsbergen Current. The Polar Surface Water, PML and Halocline are potential fresh water sources. There is no halocline present in the Nansen Basin. The lower halocline in the Canada Basin is different from the halocline in the Makarov and Amundsen basins (apart from it being pressed down by the presence of the Pacific water). Halocline formation takes place by melting of the sea ice and subsequent haline convection. The Fram Strait and Barents Sea branches meet at the slope between the Kara Sea and East Siberian Sea. North of Fram Strait, in Fram Strait and at the Greenland shelf between 75°N and 68°N the outflowing Barents Sea branch and Fram Strait branch lower halocline waters meet and mix together.

Transfer of heat and freshwater is manifested in the changes in ΘS properties and a quantification of these changes is necessary to determine the climatically important fluxes. But only a simplified classification can be used for mooring data (probably also for models). In the western part of Fram Strait a disorganised recirculation of WSC Atlantic water is observed. There is no distinction between uPDSW from Eurasian and Canadian Basins. The high salinity “Dense AW” is present. Canadian Basin Deep Water is observed in mid-depth at the slope while the Eurasian Basin Deep Water forms the densest water mass in the strait. The water mass classification should be based on the water mass boundaries on density surfaces. A test if the flow of the different water masses corresponds to the assumed source areas is also suggested. TS slopes are difficult or impossible to detect from the transport based TS properties.

Characteristics of the in- and outflows and surface waters based on geostrophic transports were presented with splitting into the western slope, western deep, eastern deep and eastern slope regions as well as for distinct water masses: the Atlantic waters and intermediate together with deep waters. A detailed classification of the water masses and its 'simplified working version' were proposed and can be found in Appendix 2.

The first day of ASOF-N seminar was closed after a short discussion on the integration and synthesis of the project results.

The second day of ASOF-N meeting, December 7 started with a brief review of the former day presentations and discussions done by *Eberhard Fahrbach.* All speakers were asked to deliver the short abstracts for the reporting purposes. The requirements for the annual ASOF-N report were also reminded.

After that *Beatriz Balino*, Project Manager of MOEN(ASOF-E) provided the essential clues how to fill and compile the Technological Implementation Plan of the project (eTIP for the electronic version). eTIP should contain a description of the results of the project as well as plans how to use them (exploitation). While for EU eTIP is a measure of the project's impact and a source of arguments for the future R&D programmes, it also suggests new research and/or projects to the scientific community. Moreover eTIP summarises the intellectual property of the results in a clear way. The eTIP should contain the general project information and a list of the results. Each result has one or more Project Partner owners. Each owner will have an exploitation plan if he exploits the result himself. Besides the new knowledge the results can include reports (handbooks, guidelines), data (statistics, calibration, trends, etc.), software (algorithms, model code, etc.), educational materials (lectures, courses notes, CDs), dissemination issues (websites, workshops, conferences) and scientific publications. Potential applications can be found as an input to the EU policies (treaties, conventions) and advisory boards as well as for further research and educational purposes. The TIP can be done by the coordinator who completes all details on behalf of all partners on the basis of informations provided by the partners in due time. The TIP process should include the following steps: identifying the results, agreement on their category (usable outside consortium, usable exclusively within consortium, non usable), identifying applications or users, identifying the owner of the result and the contact person or institution.

It was proposed for ASOF to adapt the MOEN structure of TIP results with subcategories: new data (time series, calibrations, trends, statistics), new knowledge (budget inflows/outflows, variability inflows/outflows, improved model parametrization and integrated monitoring scheme), and methodology and technological development (new methods, new instruments). Coordination of all ASOF TIPs (ASOF-N, ASOF-W, MOEN) by their project managers was also agreed upon.

After the coffee break a discussion on the cruise planning in 2005 took place, moderated by *Eberhard Fahrbach*. In **WP1** a summer cruise of r.v. 'Oceania' will be performed in June/July with a standard set of sections between Norway and northern part of Svalbard. The recovery of floats and moorings (current meters and echo sounders) in the Norwegian Sea (**WP1**) followed by hydrographic sections is planned during May/July cruises of r.v. 'Johan Hjort' and r.v. 'G.O. Sars'. Several other cruises are planned in 2005 in both **WP1** and **WP2**. These cruises include recovering and deploying current meters and ADCPs in the Fugløya-Bear Island section (Barents Sea Opening) and hydrographic measurements along standard sections: Svinøy-NW (5 times), Gimsøy-NW (5 times), Bear Island West (2 times), Fugløya-Bear Island (BSO, 6 times). Recovering/deploying of moorings in the BSO will take place during August/September cruise. The ASOF-N moorings in central and eastern part of Fram Strait (**WP3**) will be redeployed during the summer cruise of r.v.'Polarstern' in July/August together with a standard CTD section across the strait. Two cruises will take place in a frame of **WP4**. The winter cruise of r.v. 'Lance' assisted by a coastguard vessel will take place in May, including the launch of AXCTDs into the leads as well as the first tests of gliders in Fram Strait. The second cruise of r.v. 'Lance' in September will cover redeployment of moorings in western Fram Strait and CTD sections.

Marietta Weigelt (AWI) presented the updated ASOF-N website (**WP5**) which is developed and maintained by Alfred Wegener Institute. Several changes and improvements which were decided during ASOF-N meeting in 2003 have been implemented, for example 'Events' and 'Links' pages and separate webpages for reports and results/publications. In 'Data Management' section a detailed information on delivering the cruise reports and processed data sets was added as well as a direct link to the ASOF-N data store in the Oceanographic Observations Database.

Gerd Rohardt (AWI) described the data management in ASOF-N (**WP5**) with a practical on-line presentation how to access the AWI database using the tools accessible from the AWI web site (http://www.awi-bremerhaven.de/OZE/index.html). Summary of data sets which were received to be loaded into the database was presented separately for CTD and mooring data with statements on their availability (present or in near future). Technical issues on the RCM7/8 data processing (threshold interpolation) was also briefly mentioned. Matlab routines for loading CTD and mooring data from the database were presented as well as Ocean Data View software for their visualisation. In the afternoon a short training on using ODV and PERPLEX (the cruise planning software developed in AWI) took place for those who were interested in a practical use of AWI software.

All participants were reminded that their contributions to the project annual report and cost statements should be submitted to the ASOF-N coordinator until January 31. The deadline for submission of the Periodic Report and Integrated Cost Statement is February 28.

Closing the ASOF-N seminar, *Eberhard Fahrbach* thanked to all participants for their interesting presentations and fruitful discussions. The next ASOF-N meeting was decided to be a final project meeting. The exact date and place will be given later.

Appendix 1

List of participants:

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Appendix 2

a) List of deliverables

Deliverable	Deliverable title	Target month	Delivery date	Nature	Status
D 1.1	Status report of existing data	12	31.12.03	Report	**OK**
D 1.2	Status report of float deployment	24 36	31.12.04 31.12.05	Report Report	
D 1.3	Calibrated float data, current fields	36	31.12.05	Data set, Report	
D 1.4	Preliminary data from hydrographic surveys CTD, ADCP	15 27 37	31.03.04 31.03.05 31.01.06	Data set, Report Data set, Report Data set, Report	
D 1.5	Calibrated data, T/S and ADCP current fields	18 30 39	30.06.04 30.06.05 31.03.06	Data set, Report Data set, Report Data set, Report	
D 1.6	Merged modelled and observed fields of currents and water mass properties	39	31.03.06	Data set, Report	
D 2.1	Status report of existing data	12	31.12.03	Report	**OK**
D 2.2	Preliminary data from CM	15 27	31.03.04 31.03.05	Data set, Report Data set, Report	
D 2.3	Preliminary data from repeat sections with CTD and ADCP	15 27 37	31.03.04 31.03.05 31.01.06	Data set, Report Data set, Report Data set, Report	
D 2.4	Calibrated data, Analysis of time series and historical data	18 30 39	30.06.04 30.06.05 31.03.06	Data set, Report Data set, Report Data set, Report	
D 2.5	Estimates of fluxes of volume, heat and salt	36	31.12.05	Data set, Report	
D 2.6	Comparison of modelled and measured fluxes	39	31.03.06	Report	
D 3.1	Status report of existing data	12	31.12.03	Report	**OK**
D 3.2	Preliminary data from moored array and repeated sections (CM, DCM, ADCP, CTD)	16 28 37	30.04.04 30.04.05 31.01.06	Data set, Report Data set, Report Data set, Report	
D 3.3	Calibrated data, calculated fluxes, data reports	18 30 39	30.06.04 30.06.05 31.03.06	Data set, Report Data set, Report Data set, Report	
D 3.4	Time series of models and observations, analysis and interpretation of flux variability	39	31.03.06	Data set, Report	
D 3.5	Comparison between model and observed statistics of the heat flux	39	31.03.06	Data set, Report	
D 4.1	Status report of existing data	12	31.12.03	Report	**OK**
D 4.2	Preliminary data from moored array and repeated sections (CM, ULS, DCM, ADCP, CTD)	16 28 37	30.04.04 30.04.05 31.01.06	Data set, Report Data set, Report Data set, Report	
D 4.3	Calibrated data, calculated fluxes, data reports	18 30 39	30.06.04 30.06.05 31.03.06	Data set, Report Data set, Report Data set, Report	
D 4.4	Time series of models and observations, analysis and interpretation of flux variability	39	31.03.06	Data set, Report	
D 4.5	Comparison of model and observations	39	31.03.06	Report	
D 5.1	ASOF-N-www-homepage installed	6	30.06.03	Report	**OK**
D 5.2	Reference material on data matters provided	15	31.03.04	Report	
D 5.3	Data-inventories, project data, historical data	12 24 39	31.12.03 31.12.04 31.03.06	Data set, Report Data set, Report Data set, Report	**OK**
D 5.4	Project CD-ROM	39	31.03.06	Data set, Report	
D 6.1	Water mass classification and time evolution of water mass properties	12	31.12.03	Report	**OK**

D 6.2	Identification of active processes and estimates of their strength and time (forcing) dependence	39	31.03.06	Report	
D 6.3	Report with description of array performance	26	28.02.05	Report	
D 6.4	Report with description of variability characteristics	39	31.03.06	Report	
D 6.5	Report with results from sensibility study to instrument reduction	39	31.03.06	Report	

b) List of milestones

WP1 Milestones
(1-3) Annual oversights on WP-progress available, months 14, 26, 39.
(4-5) Annual water mass distributions available months 24, 36.
(6-7) Annual flow pattern available months 24, 36
(8) Analysis of variability in space and time completed, month 39.

WP2 Milestones
(1-3) Annual oversight on WP-progress available - months 14, 26, 39.
(4-5) Annual water mass distributions available - months 24, 36.
(6-7) Annual flow pattern available - months 24, 36.
(8) Fluxes of volume, heat and salt across western Barents shelf available with analysis of variability in space and time, including results form statistics on significance of longer-term measurements in selected locations - month 39.

WP3 Milestones
(1-3) Annual oversight on WP-progress available - months 14, 26, 39.
(4-5) Annual water mass distributions available - months 24, 36.
(6-7) Annual flow pattern available - months 24, 36.
(8) Volume and heat flux estimates with analysis of variability in time completed - month 39.

WP4 Milestones
(1-3) Annual oversight on WP-progress available - months 14, 26, 39.
(4-5) Annual water mass distributions available - months 24, 36.
(6-7) Annual flow pattern available - months 24, 36.
(8) Freshwater flux estimates with analysis of variability in space and time completed - month 39.

WP5 Milestones
(1) ASOF-N homepage installed, reference material for ASOF-N participants on data matters distributed - month 6.
(2-4) Summaries on data flow provided to co-ordinator and steering committee - months 14, 26, 39.
(5) Project CD-ROM distributed - month 39.

WP6 Milestones
(1) Historical data worked up - month 12.
(2) Water mass classification available - month 16.
(3) Regional correlations available from measurements and models - month 24.
(4) Technical performance evaluated - month 39.
(5) Array design optimised - month 39.

Appendix 3

a) Water mass definitions originally derived for Fram Strait (Friedrich et al., 1995; Rudels et al., 1999b) modified to include the less dense Polar waters. The separation of water masses in the Nordic Seas is rudimentary. The $\sigma_{1,5}$ and $\sigma_{2,5}$ isopycnals correspond to the densities at the sill depth of the Lomonosov Ridges and Fram Strait respectively.

Water mass boundaries	Water masses	Origins, remarks
$\sigma_\theta \leq 27.70$ Upper waters		
$\sigma_\theta \leq 27.20$, $\Theta \leq 0$	Polar Water I (**PW I**)	Includes the Pacific inflow, the PML, shelf water and the upper halocline.
$27.20 < \sigma_\theta \leq 27.70$, $\Theta \leq 0$	Polar Water II (**PW II**)	Includes the Atlantic derived lower halocline and the winter mixed layer in the Nansen Basin and the Barents Sea.
$27.70 < \sigma_\theta \leq 27.97$ Atlantic waters		
a) $27.70 < \sigma_\theta \leq 27.97$, $2 < \Theta$;	Atlantic Water (**AW**) & Re-circulating Atlantic Water (**RAW**)	Norwegian Sea and West Spitsbergen Current
a) $27.70 < \sigma_\theta \leq 29.97$, $0 < \Theta \leq 2$ b) $27.70 < \sigma_\theta \leq 27.97$, $\Theta \leq 0$, $S \leq 34.676 + 0.232\Theta$	Arctic Atlantic Water (**AAW**)	Arctic Ocean: b) includes the Arctic Ocean thermocline.
$27.97 < \sigma_\theta$, $\sigma_{0,5} \leq 30.444$ Intermediate waters		
$27.97 < \sigma_\theta$, $\sigma_{0,5} \leq 30.444$, $0 < \Theta$	Dense Atlantic (**DAW**) & Re-circulating Atlantic Water (**DRAW**)	Θ increasing, S decreasing with depth.
$27.97 < \sigma_\theta$, $\sigma_{0,5} \leq 30.444$, $0 < \Theta$	Dense Arctic Atlantic Water (**DAAW**)	S increasing, Θ decreasing with depth.
$27.97 < \sigma_\theta$, $\sigma_{0,5} \leq 30.444$, $\Theta \leq 0$	Arctic Intermediate Water (**AIW**)	Greenland Sea: includes a salinity minimum, in the Greenland Sea also a temperature minimum.
$27.97 < \sigma_\theta$, $\sigma_{0,5} \leq 30.444$, $\Theta \leq 0$	Upper Polar Deep Water (**uPDW**)	Arctic Ocean: S increasing, Θ decreasing with depth
$30.444 < \sigma_{0,5}$, $\sigma_{1,5} \leq 35.142$, Deep waters I		
$30.444 < \sigma_{0,5}$, $\sigma_{1,5} \leq 35.142$, $S \leq 34.915$	Nordic seas Deep Water I (**NDW I**)	Greenland. Includes GSDW, ISDW, NSDW.
$30.444 < \sigma_{0,5}$, $\sigma_{1,5} \leq 35.142$, $-0.6 < \Theta$, $34.915 < S$	Canadian Basin Deep Water (**CBDW**)	Canadian Basin
$30.444 < \sigma_{0,5}$, $35.142 < \sigma_{1,5}$, $\Theta \leq -0.6$, $34.915 < S$	Eurasian Basin Deep Water I (**EBDW I**)	Eurasian Basin
$35.142 < \sigma_{1,5}$, $\sigma_{2,5} \leq 39.738$, Deep waters II		
$35.142 < \sigma_{1,5}$, $\sigma_{2,5} \leq 39.738$, $S \leq 34.915$	Nordic seas Deep Water II (**NDW II**)	Greenland Sea. Includes GSDW, ISDW, NSDW.
$35.142 < \sigma_{1,5}$, $\sigma_{2,5} \leq 39.738$, $-0.6 < \Theta$, $34.95 < S$	Canadian Basin Bottom Water (**CBBW**)	Canadian Basin
$35.142 < \sigma_{1,5}$, $\sigma_{2,5} \leq 39.738$, $\Theta \leq -0.6$, $34.915 < S$	Eurasian Basin Deep Water II (**EBDW II**)	Eurasian Basin
$39.738 < \sigma_{2,5}$, Bottom waters		
$39.738 < \sigma_{2,5}$, $\Theta \leq -1.0$, $S \leq 34.915$	Greenland Sea Bottom Water (**GSBW**)	Greenland Sea
$39.738 < \sigma_{2,5}$, $-1.0 < \Theta$, $34.93 < S$,	Eurasian Basin Bottom Water (**EBBW**)	Eurasian Basin

b) Simplified version of water mass classification

Surface water	**SW**	$\sigma_\theta<27.70$
Atlantic Water	**AW**	$27.70\leq\sigma_\theta<27.97$
Dense Atlantic Water	**DAW**	$27.97\leq\sigma_\theta$, $\sigma_{0.5}<30.444$, $0<\theta$
Intermediate water	**IW**	$27.97\leq\sigma_\theta$, $\sigma_{0.5}<30.444$, $\theta<0$
Deep Water I	**DW I**	$30.444\leq\sigma_{0.5}$, $\sigma_{1.5}<35.142$
Deep Water II	**DW II**	$35.142\leq\sigma_{1..5}$