International Sea Ice Concentration and Thickness Evaluation and Inter-Comparison Workshop

Integrated Climate Data Center - ICDC

Center for Earth System Science and Sustainability

University of Hamburg, Grindelberg 5, 20144 Hamburg, Germany

September 18-19, 2014

Report

Version 1.0 **October 08 2014**

Stefan Kern **ICDC, email: stefan.kern@zmaw.de, phone: +49 40 42838-2415**

Summary

The International Sea Ice Concentration and Thickness Evaluation and Inter-Comparison Workshop took place in Hamburg, Germany, on Sep. 18-19, 2014. It was initiated as part of work package WP4000 of the ESA-CCI Sea Ice ECV project (SICCI project, http://esa-cci.nersc.no). Main objectives of WP4000 are the evaluation of the sea ice concentration, computed from satellite microwave radiometry, and sea ice thickness, computed from satellite radar altimetry, prototype products generated by the SICCI project, the inter-comparison of these prototype products with independent data, and the user assessment and usage of the prototype products in, e.g., numerical models.

Over open water, accuracy of the sea ice concentration is better than about 1%, precision is better than 2% and hence matches the average retrieval error. Sea ice concentration and its retrieval error are stable over the periods (1992-2008 and 2002-2011). At high ice concentrations accuracy is still an issue and is of the magnitude 3-5% during winter. In the freezing season accuracy is degraded over thin ice and by snow conditions impacting the radiometric signature of the sea ice. During the melting season evolution in snow and ice morphology and melt ponds impact the radiometric signature of sea ice. Melt ponds are seen as open water and hence cause a reduction in sea ice concentration. The remaining (wet) snow and sea ice between the melt ponds could counterbalance this reduction. Contamination by land in the sensors' field-of-view is an uncertainty source for sea ice area and extent calculations and poses difficulties when comparing observations with model results.

Mean values of airborne sea ice thickness estimates such as NASA Operation Ice Bridge agree within 0.1 m with SICCI project sea ice thickness but the correlation is < 0.2. Inter-comparison with in-situ sea ice thickness observations and sea ice draft yield a positive bias of SICCI project sea ice thickness of between 0.5 and 1.0 m. An estimation of the radar altimeter freeboard accuracy and precision and hence of the sea ice thickness is pending. More research work is needed to quantify the impact of snow cover and sea ice properties on radar waveform and sampling. The sensitivity of the freeboard-to-thickness conversion to input parameters snow depth, ice and snow density and their uncertainties is investigated. For radar altimetry accurate snow depth and ice density are similarly important. The lack of accurate present-day information about snow depth on sea ice hampers accurate sea ice thickness retrieval in both hemispheres. An advance in sea ice thickness evaluation would require more direct observations of sea ice freeboard, snow depth, and especially sea ice thickness. With the exception of direct drill hole measurements of the sea ice thickness all other methods also only provide a parameter, which – similar to the satellite radar altimeter freeboard – needs to be converted into sea ice thickness.

General Information about the Workshop

The International Sea Ice Concentration and Thickness Evaluation and Inter-Comparison Workshop (henceforth: Hamburg Sea Ice Workshop) took place in Hamburg, Germany, on Sep. 18-19, 2014 (see the agenda in appendix A for timing, oral and poster presentations).

The Hamburg Sea Ice Workshop was initiated as part of the work package WP4000 of the ESA-CCI Sea Ice ECV project led by the Nansen Environmental and Remote Sensing Center - NERSC (see the web page at NERSC for a project description: http://esa-cci.nersc.no). Main objectives of WP4000 are

- Evaluation of the sea ice concentration and thickness prototype products generated by the ESA-CCI Sea Ice ECV project (henceforth: SICCI project)
- Inter-comparison of these prototype products with independent data sets
- User assessment and usage of the prototype products in, e.g., numerical models

Hamburg has the overall lead of WP4000 and hence organized the Hamburg Sea Ice Workshop to foster communication between the observing and the modelling communities, and to present the work done within the SICCI project to an international user auditorium.

Funding was applied for from two organizations, namely the Center of Excellence for Climate System Analysis and Prediction (CliSAP) and Climate and Cryosphere (CliC) and hence the World Climate Research Program (WCRP). Support was granted from CliSAP: 9000 Euro, and CliC: about 6200 CHF. The funding was used for invitation letters, stationary material, catering and beverages, travel costs, and accommodation.

Invitations were sent out via Cryolist, published on the SICCI project web page at NERSC and at the ICDC web page. Invitations were also sent out to mailing lists existing within the SICCI project consortium from, e.g., the user questionnaire performed at the beginning of the project, and to other mailing lists generated in the context of i) the DACA conference in Davos 2013 and ii) the IICWG/ICE-ARC workshop on sea ice modeling and data assimilation in Toulouse 2014. Invitations were also spoken out to key individuals.

About 55 registered participants (see Annex B) plus a number of people from CliSAP attended the workshop.

The workshop was held in room 022/023 and the foyer in front of this room in the ZMAW building of the University of Hamburg. Oral presentations were given in the room while in the foyer the coffee and lunch breaks took place contemporary with the poster presentations. Warm lunch was provided on both workshop days.

The workshop's key questions

Do currently available sea ice data sets allow for a complete understanding of all relevant processes in Polar Regions? If not: What is missing? What needs to be improved?

How can we improve identification and mitigation of inconsistencies in sea ice observations?

How well do we understand uncertainties in sea ice products from observations?

What are the problems and limitations of using sea ice observations from a modeler's view point?

During the workshop, one more key question was added:

What other data sets than sea ice, e.g., albedo, cloud cover & type, sea surface temperature, chlorophyll-a concentration, …, do we need for complete understanding of all relevant processes in Polar Regions?

The workshop's main flow

The main questions were presented at the beginning of the workshop followed by two presentations during which the scene was set from the observers' as well as the modelers' view point. One of the important outcomes of these two talks was that history showed that the two communities always learned from each other and that continued collaboration is the way to continue. Afterwards the workshop dived into the SICCI project with sessions: "What do we get from the SICCI project?" and "What do we get with SICCI project prototype products?" The main goals of these sessions, whose presentations were given by members or associates of the SICCI project consortium, were to

- explain how and why the individual input data sets and retrieval methods were used to generate which SICCI project prototype product
- show how the individual SICCI project prototype products have been used in numerical modelling studies and which results were obtained in doing so

These two sessions were followed by two sessions in which international participants outside the SICCI project consortium gave presentations about their work related to sea ice data sets, both observations and modeling. These did partly also include SICCI project prototype products. A wrap-up discussion session which came back to the initial questions closed the day. The focus of the discussion was on sea ice concentration and sea ice thickness.

On the second workshop day members of the SICCI project consortium presented results of the evaluation and validation activities done merely within the SICCI project. These were discussed thoroughly. This was followed by presentations "looking beyond the plate" in which potential future activities and preliminary results which could be of importance for the SICCI project phase 2 and which underline the importance of a continuation of this work were presented. In particular the role of Cryosat-2 and SMOS was highlighted and the workshop participants learned about the impact of the shrinking Arctic sea ice cover to mid-latitude weather and climate. The workshop was closed by the SICCI project science manager with an outlook into future activities in the context of this project and with a final discussion.

Three coffee breaks and two lunch breaks allowed for a total of four hours to view the 17 posters and discuss their results. Posters nicely fit with the workshop key questions and either had a special key issue related to these questions as focus or pointed towards established and future potential application and collaboration areas with regard to the SICCI project and the SICCI project prototype products.

Workshop Results

Sea Ice Concentration

Sea ice concentration (SIC) or sea ice area fraction is the best studied sea ice parameter based on satellite remote sensing data. Still, even though this is the case, the Hamburg Sea Ice Workshop pointed out the need for further improvement in the following areas:

- Accuracy in regions with open water is reasonable. The bias is below about 1% and the standard deviation is below 2%. SIC uncertainty time series tend to show a trend which could either be caused by atmospheric conditions changing over the time period investigated or by inconsistencies in open water tie points and/or the correction for the weather influence applied. This will be one of the major areas of investigation in SICCI project phase 2.

- Limited accuracy in regions with high SIC is still an issue. During the freezing season the accuracy is primarily degraded by snow conditions and their impact on the radiometric signature of the sea ice. This will be one of the major areas of investigation in SICCI project phase 2.

- Biases exist in areas of thin sea ice even though the SICCI SIC retrieval algorithm has been selected such that the impact of sea ice thickness is minimal. Thin ice shall be flagged in future version of the SICCI SIC product.

- Biases exist in areas of melting sea ice and melt ponds. Melt ponds are seen as open water by microwave radiometry. Hence summer SIC computed from microwave radiometry should under-estimate actual SIC. However, some SIC retrieval algorithms still provide SIC close to 100% or even above 100% in regions of close to 100% actual SIC. It is therefore likely that the radiometric signature of the actual sea ice fraction, i.e. the sea ice between the melt ponds, is such that the effect of the melt ponds on the radiometric signature (= the one of open water) is compensated. This is going to be investigated further within the SICCI project but also outside the SICCI project. Melt conditions and/or potential coverage with melt ponds should be flagged in future version of the SICCI SIC product.

- The current treatment of contamination of near-coastal grid cells by land causes difficulties when using the SICCI SIC prototype product for inter-comparison studies and for assimilation studies. This will be one of the major areas of investigation in SICCI project phase 2.

With regard to the SIC evaluation approach and results no substantial criticism was given.

Open questions (for the SICCI consortium) are:

- What is the spatial correlation of uncertainties in the SICCI SIC prototype product?

- How will contamination of near-coastal grid cells by land be treated in future SICCI SIC products?

A discussion along the philosophical question: “Which sea ice concentration do we want to have?” revealed the two different groups among the workshop participants. One group asks more what the users wish to have and to not care too much about whether the values provided are physically meaningful. That is, if a SIC retrieval algorithm provides 100% SIC in an area with melt ponds and the actual SIC is 100% then the user is satisfied. The other group is less concerned about what the users want and more interested in providing a physically consistent product. That is, if sea ice of 100% is covered by a certain amount of melt ponds then the algorithm shall provide a physically consistent SIC value below 100%. This question triggered a lot of discussions about usage of flags which aid and encourage users to make their own decision about whether the data is useful or not.

Sea Ice Thickness

Sea ice thickness (SIT) is estimated within the SICCI project using satellite radar altimetry. Due to delays in input data set availability only a 10-year long time series of SIT was produced and has been evaluated. The results of these evaluations are quite diverse. Generally the following statements can be made.

- A comparison of SICCI SIT to Operation Ice Bridge (OIB) SIT provided a surprisingly small mean difference of about 0.03 m. However, individual differences between SICCI and OIB vary a lot and the correlation between collocated SICCI and OIB SIT data is close to zero

- SICCI SIT was compared to airborne EM sounding. Similar to the comparison with OIB data correlations are quite low (less than 0.6). RMSD between EM and SICCI SIT range between 0.34 m and 1.72 m; it has to be kept in mind that the EM data are total SIT, i.e. sea ice thickness plus snow depth.

- SICCI SIT (and freeboard) inter-comparison with in situ measurements from North-Pole (NP) drifting stations reveal a clear positive bias of the current SICCI SIT prototype product; the bias is between 0.5 and 1 meter.

- SICCI SIT inter-comparison with the complete BGEP moored ULS data set confirm the results of the inter-comparison with NP drifting station and show a bias of between 0.5 and 1 meter. The seasonal cycle in SIT provided by SICCI SIT data is just half the one measured by BGEP ULS. In another comparison with Fram Strait moored ULS data again SICCI SIT are positively biased and do not confirm the negative trend in SIT observed by the ULS.

- Pending are an inter-comparison with ICESat-1 SIT and with submarine ULS data.

As with regard to the SIT evaluation approach and results no substantial criticism was given.

It was noted that many of the SIT data used for inter-comparison are not direct SIT measurements. Either we have total (sea ice + snow) thickness or the thickness needs to be derived from either draft or freeboard measurements based on essentially the same assumptions about isostacy, sea ice, snow, and water densities and snow depth. This limits the value of these inter-comparisons.

However, results obtained from some of the inter-comparisons agree with the result obtained using the NP drifting station data.

One major influencing factor in the SIT retrieval is snow depth. It was pointed out at the workshop that current knowledge about snow depth is limited. Snow depth data sets are either limited to certain ice types, i.e. first-year ice in case of using microwave radiometry, and environmental conditions, e.g., freezing conditions, or are outdated as they are based on climatologies from measurements conducted decades ago. Common to all snow depth data sets is an unknown uncertainty. It was stressed that improved knowledge of snow depth and snow cover properties is essential for both advancing SIC retrieval and SIC uncertainty estimation and improve SIT estimation from satellite altimetry. For this, more validation studies of currently available snow depth products, more in-situ measurements of snow depth and snow cover properties, and search for alternative retrieval methods are required.

User Feedback

A number of studies already used SICCI project data; either SIC or SIT but also both data sets. From the workshop participants who presented related work we learned the following

- Format and way of data distribution are fine; no complaints heard. However, the SIT data set would benefit from a better guide as to how to use the data. In particular the fact that the number of measurements per grid cells could (and should) be used as a quality measure should be communicated.

- It is important to communicate and document where the data (here particularly the SIT) are reliable. Note: Currently the SICCI SIC comes WITH uncertainties while the SICCI SIT prototype product does not. The reason for this – as was also communicated during the workshop – is the inability to provide (yet) a proper uncertainty estimate of the radar altimeter freeboard. This will be one of the major areas of investigation in SICCI project phase 2.

- For climate studies (NorESM1) the time series of data offered currently is too short.

- Usage and application of the current SICCI prototype products in operational systems and for seasonal predictions is not possible or at least limited. Products can only be used for hindcast computations to potentially improve the models used.

- The large spatial data gaps in the current SICCI SIT product are problematic for assimilation of the data into models and is severe limitation of the usefulness of the data for studies involving, e.g., nudging. It was pointed out that one could try to fill the pole hole with a combined product from SIT proxy data such as ice type, ice age, surface temperature and additional information from either re-analysis or other, independent SIT sources.

- It was discussed whether it wouldn't be better to use freeboard instead of SIT, e.g., for inter-comparison with models. Freeboard and snow depth are usually variables which are well known in a model. In contrast, on the observers' side, freeboard still needs to be evaluated and has a number of uncertainty sources. However, the uncertainties in SIT derived from this

freeboard are substantially larger due to the uncertainty contributions from snow depth and the choice of densities used for the freeboard-to-thickness conversion. These contributions are not yet accurately known as was also pointed out during the workshop.

- It was also discussed whether it would be possible to provide an actual SIT distribution per grid cell rather than one single mean and/or modal value. This is limited by the nature and noise of the elevation measurement provided by the altimeters. In principle one could provide all single measurements of freeboard and hence also SIT. However, the variation between adjacent freeboard and hence SIT estimates (the noise) could be so high that it does not make sense physically. This will be one of the major areas of investigation in SICCI project phase 2.

- The current status in freeboard retrieval using Cryosat-2 data was presented with special focus on uncertainty estimation. It was demonstrated – in accordance with earlier studies and evaluation results from the SICCI SIT prototype product – that it is less the precision one needs to worry about but that many bias sources exist, e.g., preferential floe sampling, sea surface height bias, and radar waveform modulation and penetration issues due to varying snow cover properties and ice-snow interface roughness variations. Improvement of the radar waveform and re-tracker are among the main areas of investigation in SICCI project phase 2 to improve freeboard retrieval and to permit reliable freeboard uncertainty estimation.

Further issues discussed & mentioned

A number of comments came from ESA:

- It seems strange to ESA that within the sea ice community efforts towards building a satellite simulator are so slow. In most of the other ESA CCI ECV projects such a simulator exists and has greatly helped to advance knowledge. It should be the way forward here as well.

- We are encouraged by ESA to include more flags into our products. It was discussed that this might not be a straightforward thing to do and might involve additional data such as from re-analyses which is something we so far tried to avoid in order to keep SICCI products as "clean" of model results as possible. This was acknowledged by ESA as a good thing to do and to keep.

- ESA advertised usage of SMOS data. The extension of the SMOS life time makes it a powerful candidate for a number of input data for the SICCI project products – as was demonstrated at the workshop: thin ice thickness, summer ice concentration, snow depth on thick sea ice. Actually, SMOS data are going to play an important role in SICCI project phase 2.

It was shown and agreed that sea ice drift and – related to this – sea ice deformation are essential parts of the sea ice ECV. It was demonstrated – in agreement with recent publications – that the investigation of sea ice area and volume changes is required to better understand current sea ice cover variability in both Polar regions (such as the cause for the recent two minima in Arctic sea ice area in 2007 and 2012) and to separate contributions to sea ice thickness and volume from dynamic and thermodynamic processes. Deformation is important for the dynamic sea ice volume change and

– as has been shown on the workshop – has the potential to improve current snow depth on sea ice estimates. Sea ice drift is going to be included into the SICCI project phase 2; however no sea ice drift product will be generated.

It is noted that there is a lack of validation data for snow depth, sea ice thickness, and freeboard particularly in the Antarctic. This is in particularly important, because the environmental conditions force the sea ice – snow system to develop in a different manner than in the Arctic. Hence sea ice parameter retrieval procedures developed for the Arctic might not be easily transferred and applied to Antarctic conditions. This applies especially to the freeboard retrieval using radar altimetry which, in the Antarctic, suffers from i) a substantially smaller sea ice freeboard than in the Arctic, and from ii) a much more layered snow pack.

Appendix A: AGENDA

International Sea Ice Concentration and Thickness

Evaluation and Inter-Comparison Workshop

University of Hamburg, ZMAW Building, Bundesstrasse 53, 20146 Hamburg

18./19. September 2014

A G E N D A

Do currently available sea ice data sets allow for a complete understanding of all relevant processes in Polar Regions? If not: What is missing? What needs to be improved?

How can we improve identification and mitigation of inconsistencies in sea ice observations?

How well do we understand uncertainties in sea ice products from observations?

What are the problems and limitations of using sea ice observations from a modeler's view point?

T H U R S D A Y

Setting the scene [Kern, S.]

9:00-9:10	Opening & Welcome
9:10-9:30	Setting the Scene: Observations [Stefan Kern et al.]

9:30-9:50	Sea ice observations in numerical models: What has been done? What are the next steps? [Martin Vancoppenolle]
9:50-10:20	***Coffee & Posters & Discussion***

What do we get from SICCI? [Kaleschke, L.]

10:20-10:30	ESA SICCI project: Aims and products [Stein Sandven]
10:30-10:50	SIC algorithm selection & SIC production & future plans [Leif Toudal Pedersen, et al.]
10:50-11:10	SIT algorithm studies & SIT production & future plans [Eero Rinne, et al.]

What do we get with SICCI products? [Kern, S.]

11:10-11:30	Using SICCI ice concentrations and thickness to nudge sea ice in an Earth System Model [Felix Bunzel and Dirk Notz]
11:30-11:50	Sea ice assimilation with adjoint method [Nikolay Koldunov, et al.]
11:50-12:10	An evaluation of NorESM1 sea ice simulations based on SICCI SIC and SIT datasets [Jens Debernard]
12:10-13:10	***Lunch***

Some related key sea ice studies [Beitsch, A.]

13:10-13:30	PMW SIC inter-comparisons [Joey Comiso]
13:30-13:50	AMSR2 SIC with uncertainties [Walt Meier, et al.]
13:50-14:30	***Coffee & Posters & Discussion***

Some related key modeling activities [Notz, D.]

14:30-14:45	Model requirements of sea ice concentration and thickness in the Arctic [Wieslaw Maslowski]
14:45-15:00	Forecasting future sea ice conditions in the MIZ: A Lagrangian Approach [Bruno Tremblay]
15:00-15:15	The Status and Development of the Regional Ice Prediction System [Tom Carrieres]
15:15-15:30	Sea Ice Analysis and Forecasting with the GloSea5 Seasonal Forecast System [Andrew Peterson]

15:30-16:00 Discussion / Wrap-up of the day / Review of the key questions

F R I D A Y

9:00-09:10 Housekeeping & wrap-up of yesterday

Validation & Evaluation of SICCI prototype products [Willmes, S.]

09:10-09:35 SIC: validation against 0% and 100%; uncertainties, off-range, Landsat, melt pond fraction) [Stefan Kern et al.]

09:35-10:00 SIT validation & inter-comparison: SICCI (in-situ, EM, OIB, ULS) [Marta Zygmuntowska, Kirill Khvorostovsky, et al.]

10:00-10:20 About snow on sea ice [Stefan Kern, et al.]

10:20-11:20 Coffee & Posters & Discussion

11:20-12:00 Discussion: Where are we? Where do we go?

12:00-13:00 Lunch

Where do we go from here? [Kern, S.]

13:00-13:10 SMOS Mission overview and status after 5 years in orbit [Matthias Drusch, et al.]

13:10-13:30 The ESA STSE project SMOS+ Sea Ice: Towards a synergy of SMOS and Cryosat-2 [Lars Kaleschke, et al.]

13:30-13:50 Uncertainties of Sea Ice Thickness from Cryosat-2 [Stefan Hendricks, et al.]

13:50-14:10 What we learned about SIC as boundary conditions from model simulations [Jinro Ukita]

14:10-14:25 Plans for SICCI phase-2 addressing some key scientific issues for the polar regions [Stein Sandven]

14:25-15:00 Final discussion: Where do we go from here?

15:00-16:00 Coffee & Farewell

P O S T E R C O N T R I B U T I O N S

Zhijun Li Introduction on the progress of Arctic Engineering in China

Xiao Cheng Evaluation on the SICCI SIC and SIT data in specific regions of interest in Antarctic and Arctic (presented by Junshen Lu)

Steffen Tietsche	Arctic sea ice thickness over the last decade from observations and ocean re-analyses
Nina Maaß	Snow thickness retrieval from SMOS data – Sensitivity to ice temperature, ice thickness, and snow density
Sascha Willmes	The microwave emissivity variability of snow-covered first-year sea ice from late winter to early summer: a model study
Sascha Willmes	A quasi-daily pan-Arctic lead product derived from MODIS thermal infrared imagery
Andreas Wernecke	Lead detection with Cryosat-2: Method improvement and validation
Xiangshan Tian-Kunze	Estimation of thin sea ice thickness from SMOS brightness temperature in the Arctic
Florence Fetterer	Development of a combined satellite ice thickness product for use in an operational sea ice model (presented by Walt Meier)
Sara Fleury	Leads identification using Saral/Altika: Comparison with segmented MODIS thermal images
Friedrich Richter	The atmospheric response on sea ice changes
Burcu Ozsoy-Cicek	Antarctic Sea Ice Thickness from ICESat-1 using empirical Approaches based on in-situ Drillings
Burcu Ozsoy-Cicek	Progress in the Development of the Turkish Polar research program
Valentin Ludwig	Sea Ice concentrations retrieved from L-Band data (presented by Lars Kaleschke)
Georg Heygster	Thickness of thin sea ice retrieved from satellite L-Band high incidence angle observations
Yufang Ye	Improving multiyear ice concentration retrieval from passive microwave and atmospheric model data
Chang-Qing Ke	Inter-comparison between ESA CCI and NSIDC SSMI sea ice concentration products in Arctic Ocean

Appendix B: PARTICIPANTS LIST

Name	Surname	Affiliation	City	Country	e-mail
Alexander	Beitsch	Institute of Oceanography	Hamburg	Germany	alexander.beitsch@zmaw.de
Louisa	Bell	University of Hamburg	Hamburg	Germany	louisa.bell@hotmail.com
Stavroula	Biri	Institute of Oceanography	Hamburg	Germany	stavroula.biri@zmaw.de
Felix	Bunzel	Max Planck Institute for Meteorology	Hamburg	Germany	felix.bunzel@mpimet.mpg.de
Tom	Carrieres	Canadian Ice Service	Ottawa	Canada	tom.carrieres@ec.gc.ca
Josefino	Comiso	NASA Goddard Space Flight Center	Greenbelt	Maryland	josefino.c.comiso@nasa.gov
Jens	Debernard	Norwegian Meteorological Institute	Oslo	Norway	jens.debernard@met.no
Matthias	Drusch	ESA-ESTEC	Noordwijk	Netherlands	Matthias.Drusch@esa.int
Sara	Fleury	CTOH/LEGOS	Toulouse	France	sara.fleury@legos.obs-mip.fr
Stefan	Hendricks	Alfred Wegener Institute	Bremerhaven	Germany	stefan.hendricks@awi.de
Georg	Heygster	University of Bremen, Institute of Environmental Physics	Bremen	Germany	heygster@uni-bremen.de
Nicholas	Hughes	Norwegian Ice Service	Tromsø	Norway	nick.hughes@met.no
Marcus	Huntemann	University of Bremen, Institute of Environmental Physics	Bremen	Germany	marcus.huntemann@uni-bremen.de
Mikhail	Itkin	Norwegian Meteorological Institute	Tromsø	Norway	mikhail.itkin@met.no
Lars	Kaleschke	University of Hamburg	Hamburg	Germany	lars.kaleschke@zmaw.de
Frank	Kauker	Alfred-Wegener-Institut	Bremerhaven	Germany	frank.kauker@awi.de
Changqing	Ke	Nanjing University	Nanjing	China	kecq@nju.edu.cn
Stefan	Kern	Integrated Climate Data Center, Center for Earth System Science and Sustainability, University of Hamburg	Hamburg	Germany	stefan.kern@zmaw.de
Kirill	Khvorostovsky	Nansen Environmental and Remote Sensing Center	Bergen	Norway	kirill.khvorostovsky@nersc.no
Nikolay	Koldunov	Institute of	Hamburg	Germany	nikolay.koldunov@zmaw.de

		Oceanography, University of Hamburg			
Thomas	Lavergne	Norwegian Meteorological Institute	Oslo	Norway	t.lavergne@met.no
Matti	Leppäranta	University of Helsinki	Helsinki	Finland	Matti.lepparanta@helsinki.fi
Zhijun	Li	State Key Laboratory of Coastal and Offshore Engineering, Dalian University of Technology	Dalian	China	lizhijun@dlut.edu.cn
Junshen	Lu	University of Bremen, Institute of Environmental Physics	Bremen	Germany	lujunshen11@hotmail.com
Nina	Maaß	University of Hamburg	Hamburg	Germany	nina.maass@zmaw.de
Marko	Mäkynen	Finnish Meteorological Institute	Helsinki	Finland	marko.makynen@fmi.fi
Wieslaw	Maslowski	Naval Postgraduate School	Monterey	USA	maslowsk@nps.edu
Walter	Meier	NASA Goddard Space Flight Center	Greenbelt, Maryland	USA	walt.meier@nasa.gov
Christian	Melsheimer	University of Bremen, Institute of Environmental Physics	Bremen	Germany	melsheimer@uni-bremen.de
Marcel	Nicolaus	Alfred-Wegener-Institut	Bremerhaven	Germany	marcel.nicolaus@awi.de
Dirk	Notz	Max Planck Institute for Meteorology	Hamburg	Germany	dirk.notz@mpimet.mpg.de
Dirk	Olonscheck	Max Planck Institute for Meteorology	Hamburg	Germany	dirk.olonscheck@mpimet.mpg.de
Burcu	Ozsoy Cicek	Istanbul Technical University	Istanbul	Turkey	burcu@drcicek.com
Leif Toudal	Pedersen	DMI	Copenhagen	Denmark	ltp@dmi.dk
Andrew	Peterson	Met Office	Exeter	UK	drew.peterson@metoffice.gov.uk
Friedrich	Richter	Institute of Oceanography	Hamburg	Germany	Friedrich.richter@zmaw.de
Eero	Rinne	Finnish Meteorological Institute	Helsinki	Finland	eero.rinne@fmi.fi
Stein	Sandven	Nansen Environmental and Remote Sensing Center	Bergen	Norway	stein.sandven@nersc.no
Raul	Scarlat	University of Bremen, Institute of Environmental	Bremen	Germany	raul@iup.physik.uni-bremen.de

		Physics			
Lothar	Schüller	EUMETSAT	Darmstadt	Germany	lothar.schueller@eumetsat.int
Sandra	Schwegmann	AWI	Bremerhaven	Germany	Sandra.Schwegmann@awi.de
Gunnar	Spreen	Norwegian Polar Institute	Tromsø	Norway	gunnar.spreen@npolar.no
Xiangshan	Tian-Kunze	Institute of Oceanography University of Hamburg	Hamburg	Germany	xiangshan.tian-kunze@zmaw.de
Steffen	Tietsche	European Centre for Medium-Range Weather Forecasts	Reading	UK	s.tietsche@ecmwf.int
Bruno	Tremblay	McGill University	Montreal	Canada	bruno.tremblay@mcgill.ca
Jinro	Ukita	Niigata University	Niigata	Japan	jukita@env.sc.niigata-u.ac.jp
Martin	Vancoppenolle	Centre National de la Recherche Scientifique	Paris	France	martin.vancoppenolle@locean-ipsl.upmc.fr
Andreas	Wernecke	University of Hamburg	Hamburg	Germany	andreas.wernecke@zmaw.de
Sascha	Willmes	University of Trier	Trier	Germany	willmes@uni-trier.de
Yufang	Ye	University of Bremen, Institute of Environmental Physics	Bremen	Germany	yufang@uni-bremen.de
Julian	Zimmermann	German Research Centre for Geosciences	Berlin	Germany	julian.zimmermann@gfz-potsdam.de
Marta	Zygmuntowska	NERSC	Bergen	Norway	marta.zygmuntowska@nersc.no