Joint workshops to (re)formulate open research questions of joint interest: The Blue-Action-ASOF workshop and the 2nd EU Climate Modelling workshop

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Contents

Summary for publication

One of the main aims of the Blue-Action project is to establish a strong clustering activity with the European and international scientific communities focusing on climate services, Arctic impacts and Blue Growth. Our work package WP6 supports the exchange and interaction between the products and services that Blue-Action delivers and the communities focusing on those themes. The goals of this work packages are to identify open research questions/development needs, to create synergies between these projects, to share knowledge and support knowledge transfer.

Within this framework, two workshops have been organised in the first half of 2019:

- A workshop on the "Representativeness of ocean observations and Flux calculations", in collaboration with ASOF (Arctic and Subarctic Ocean Fluxes), held at the Danish Meteorological Institute (DMI) in Copenhagen (DK) on 24 -26 April 2019.
- A workshop on "Climate Prediction in the Atlantic-Arctic sector", in collaboration with the EU Climate Modelling Cluster and the Bjerknes Climate Prediction Unit (BCPU), held in Bergen (NO) on 5-7 June 2019.

The main results of these workshops can be found in this deliverable, with links to resources and materials of the workshops.

Work carried out

Blue-Action and ASOF Workshop 2019 on "Representativeness of ocean observations and Flux calculations"

Blue-Action and ASOF organised a joint workshop on the topics: "Representativeness of ocean observations and Flux calculations". The workshops was held at the Danish Meteorological Institute (DMI) in Copenhagen (DK) on 24 -26 April 2019.ASOF stands for "Arctic-Subarctic Ocean Fluxes" is an international programme on the oceanography of the Arctic and Subarctic seas and their role in climate. Its secretariat is located at AWI and the scientific coordinator is Michael Karcher (AWI). Many scientists working in Blue-Action have been active members of the ASOF network in the past years.

The Blue-Action community collaborates on a regular basis with ASOF on the following topics:

- Arctic/Subarctic synthesis of mass, heat & freshwater fluxes,
- Arctic/Subarctic ocean ecosystems and biology,
- Testing of ocean circulation and biophysical models of the Arctic and Subarctic.

More on this long-term collaboration can be read on http://www.blue-action.eu in the “Clustering” section.

At the workshop we had 45 participants joining the meeting, with 34 presentations.

In addition to presentations and discussion on the two focus topics we had numerous contributions on core ASOF topics, such as reports on the current status of the gateway moorings, new insights into the dynamics of ocean circulation and exchange between the basins, as well as Ocean-Sea Ice interaction.

Materials of the workshop

The full list of presentations with links to the web recordings can be found in Annex 1.
Webrecordings are available on the ASOF website:
https://jh.hosted.panopto.com/Panopto/Pages/Sessions/List.aspx#folderID=%222364b20c-253a-49d2-93ef-aa3900792a92%22&page=0
Presentations by Blue-Action authors have been published in Zenodo in full open access:
http://zenodo.org/communities/blue-actionh2020

Main results achieved

Outcomes of the workshop

Representativeness of ocean observations: A recurring issue in the analysis and interpretation of observational data, as well in the use of these data for model validation and data assimilation, is how their representativeness in space and time are dealt with. This issue is of particular relevance for in-situ data such as oceanic measurements from profiling devices or time series data from mooring locations. We particularly welcomed submissions dealing with questions related to representativeness and uncertainties in observations, what these mean for the observational analysis as well as the usefulness of the data in modelling, and ways forward in resolving those issues in particular in regions of sparse data coverage.

Flux calculations: We had fostered a discussion the problems related to the usefulness/ambiguity of heat- and freshwaterflux calculations across single gateways. A way forward has been agreed during the meeting. ASOF is going to release a set of recommendations on the basis of the consensus achieved, with contributions from the Blue-Action teams.

Workshop on Climate Prediction in the Atlantic-Arctic sector

This was jointly organised by the Bjerknes Climate Prediction Unit and the EU Climate Modelling Cluster on 5-7 June 2019 in Bergen (NO) and is considered the 2nd EU Modelling Cluster workshop. The EU Climate Modelling Cluster collects a number of H2020 projects working on modelling topics such as Blue-Action, APPLICATE, PRIMAVERA and CRESCENDO and the BCPU project, funded by the Trond Mohn Foundation. The cluster was initiated by the EC/EASME in May 2017 with a workshop on evaluating climate and Earth system models at the process level.

Credits: Andreas Hadsel Opsvik (Bjerknessenteret for klimaforskning)

Goals

- Identify open research questions/development needs on Climate Prediction in the Atlantic-Arctic sector.
- Create synergies between these projects.
- Share knowledge and support knowledge transfer to those working in the field.

Materials of the workshop

- Agenda of the workshop with the list of the interventions can be found in Annex 2.

- All presentations that could be disclosed in open access to the general public have been made available in Zenodo: ttps://www.zenodo.org/communities/blue-actionh2020. For those presentations still covered by confidentiality, as results are planned to be published in the next months, the authors have been made available the abstracts of their interventions in Zenodo.
- The event was web streamed on htttp://webcast.imr.no/replay/webcastShow.html?key=S2acRsnarRiHCMj for the entire three days.
- The outcomes of the panel discussion held on 5 June 2019 can be found in Annex 3.

Main results achieved

Key take-home messages from the panel discussion on 5 June 2019

Key take-home messages for policy-makers and decision-makers

Climate prediction in the Atlantic and Arctic sector is reaching useful skill levels, and research indicates that there is great potential to further enhance prediction skill. The EU researchers are leading the field, and EU funded projects have contributed to this by helping unite European research.

Improving prediction skill requires improved understanding of key processes and development of new more resolved numerical models. Critical to this are sustained long-term observations of the ocean and new observations for validating the new models. Climate modellers need to provide feedback to the observational community on required data, through workshops and by working together in projects.

Massive investments are required to develop these new models, as developments in computing infrastructure now outpace development of numerical climate models. To cope with these new challenges the climate researchers need to adopt community models, developed by large-teams, with simulations analysed by the wider scientific community

Climate services based on seasonal to decadal prediction are demanded by stakeholders. The development of useful climate services requires strong interaction between climate researchers and stakeholder partners. Greater awareness among stakeholders of the potential benefits of climate services is required to further accelerate the field.

Key take-home messages for the scientific community

Climate prediction in the Atlantic and Arctic sector is reaching useful skill levels. There appears to be great potential to enhance prediction skill in our region, as recent results indicate that current climate prediction systems underestimate the predictable component of the climate system. In particular, the high predictability of the ocean in these systems does not transfer to atmospheric circulation to the extent expected, and predictability over continents appears too low. Low forecast skill is not completely surprising, given the large morel errors, discrepancies among initial conditions in different forecast systems (especially in the large-scale ocean circulation), and initial forecast shock and drift. Although there is a general understanding of the drivers of large-scale seasonal to decadal predictability (e.g., El Niño Southern Oscillation, Atlantic multi-decadal variability), the key physical processes are still not well understood and this hampers further improvement in forecast skill.

In the short term, forecast skill can be enhanced by using large (40 members or more) single and multi-model ensembles to identify the predictable signal from chaotic atmospheric noise, and by combined dynamical-empirical approaches. At present increasing ensemble size is likely more beneficial than increasing resolution, which can lead to reduced model biases but not necessarily to enhanced prediction skill. Large-ensembles are also critical for predicting extreme event probabilities. Skill improvement can also be achieved through the development of methods to combine high-resolution and low-resolution ensembles, optimally utilize multi-model ensembles, and approaches to blend dynamical and machine-learned ensembles.

In the medium term, improved forecast skill may be achieved through the application of advanced data assimilation approaches that can make effective use of sparse data and can consistently initialize the different components of the climate system. There is also a need to develop appropriate methods to generate ensembles that sample key uncertainties in the various components of the climate system. Forecast applications often require bias correction approaches, although such corrections introduce uncertainty and can reduce skill. Refinement of *a posteriori* bias correction approaches to consider higher order moments is required. Alternative to standard dynamical bias correction can also be beneficial, as flux correction approaches are often not useful.

In the long-term, improvements in understanding of key physical processes are necessary to reduce model error and to improve forecasts. The atmospheric boundary layer in particular (where many parameterizations are active) suffers from a number of biases that need to be reduced, ranging from the polar latitudes to the tropics and from continental areas to the oceans.

Observations are critical to improve models and predictions, as well as to monitor climate. Extending together the OSNAP and RAPID measurements is important to understand how subpolar and subtropical Atlantic Meridional Overturning Circulation (AMOC) variability are connected, while measurements of the deep in the deep ocean including the overflows are need to understand the chain of events leading to multi-decadal ocean variability over the region. The development of higher resolution models demands new observations that can resolve the simulated phenomena, this requires both observational campaigns and long-term observational programmes, and for greater communication between modellers and observers. Data assimilation approaches can be used to identify key regions and variables to observe, and to provide observational uncertainty estimates.

Enhancing model resolution is a promising avenue, but eddy and convective resolving resolutions required to make stepwise improvement are beyond the reach of current computational resources. There are several major challenges facing the development of the next generation of high-resolution climate models: we need to develop strategies to use the new computer infrastructure (e.g., hybrid cpu,gpu) that are rapidly evolving and not designed for climate (weather) modelling purposes, we need an appropriately trained workforce, we need to adopt community models, while still allowing an appropriate level of model diversity. Data from high resolution models and large ensembles will need to be shared to maximize knowledge gain, and this will require community infrastructure.

Key take-home messages from topic discussions

Topic 1: Ocean and sea ice predictability

(Facilitators: Pablo Ortega and Steffen Olsen)

The discussion was centered on three specific points:

1. Constraining the limits of climate prediction through perfect model analyses

- Perfect model frameworks have been assumed in the past to provide the upper limits of climate predictability, however, recent results, like the "signal-to-noise paradox" seem to suggest that models can have higher skill predicting the real world than themselves.
- Yet, perfect model analyses can still be extremely useful, in particular to test the impact of observational uncertainties/limitations on the predictive skill, as well as to understand processes via hypothesis testing (e.g. assessing the importance of specific regions like the Subpolar North Atlantic).
- Other potential uses of these methods are investigating the predictability of unprecedented events (e.g. tipping points) and/or under future climate conditions.
- A special interest for these studies lies in the North Atlantic, a region where most decadal forecast systems exhibit high predictive skill, despite the fact that most coupled models represent the AMOC variability in a different manner. The ultimate drivers of this skill remain unclear.

2. Improving skill through better observations/initialization strategies

- Some current limitations on predictive skill relate to 1) the fact that the quality of observations is not homogeneous in time, 2) some regions/variables, like the deep ocean, are not sufficiently observed, 3) all system components are not always initialized consistently with each other (e.g. ocean, sea-ice and atmosphere), 4) observations can be highly uncertain.
- In particular, the high uncertainty in the past AMOC variability (which shows important discrepancies in the available ocean reanalyses) suggests that most forecast systems might not be initializing it correctly. This could imply that better assimilation protocols succeeding to initialize it could potentially boost the (already high) skill over the region. Indeed, it is possible that the current skill at long forecast times relates to the correct initialization of temperature anomalies and their propagation by the mean ocean circulation, with no correct initialization of the anomalous ocean circulation.
- Better physical consistency among the different components can be achieved with Ensemble Kalman Filter (EnKF) data assimilation, or similar perfect model analyses can assist in evaluating the benefits of new initialization techniques, and guide in the identification of key regions that require additional observational efforts.

3. Ocean-sea ice contributions to predictive skill over the continents

- A major limitation of most current forecast systems is the lack of skill over land, which suggests that air-sea teleconnections might not be well represented in them.
- Predictive skill at seasonal to decadal timescales is, however, achieved in regions and variables with well-known teleconnections over continents from the El Niño Southern Oscillation (ENSO), Atlantic multi-decadal variability (AMV), Barents-Kara Sea, and subpolar North Atlantic.

- Recent results identify three major strategies which could be currently used to improve the skill over land: the use of hybrid predictions (combining dynamical and statistical forecasts), performing large ensembles (40 members or more) to constrain the predictive signal on the atmospheric circulation (e.g. of the NAO), and multi-model predictions.
- For future efforts, the two most promising avenues are solving (at least some of) the long-standing systematic model biases, and performing predictions at the eddy-permitting/eddy-resolving resolution (which can themselves improve some model biases) to improve the representation of some processes, such as orographic driven precipitation, thanks to a more realistic topography.

4. Key observations to assess the realism of models (and their simulated mechanisms), evaluate/improve models

- Extending together the OSNAP/RAPID measurements over the next decade would be an important step to understand how subpolar/subtropical AMOC variability are connected, as well as the ability of models to reproduce them.
- Other measurements, in particular in the deep ocean, describing the variability of the North Atlantic and the overflows would be equally beneficial to understand the chain of events leading to multi-decadal ocean variability over the region.

Topic 2: Atmospheric predictability (timescales, drivers, seasons, domain)

(Facilitators: Panos Athanasiadis and Guillaume Gastineau)
The discussion was centered on the following specific points:

1. The sources of predictability and the underlying mechanisms (physical processes) vary with the timescale of the predictions. For example, AMOC and air-sea interactions in midlatitudes are key for decadal predictions, whilst arguably, realistically initializing snow-cover is not as important in decadal predictions. Similarly, the sources of predictability in seasonal prediction vary with the calendar season (e.g. soil-moisture is important in summer but not in winter).
2. For each particular prediction problem (forecast horizon, calendar season, area of interest, etc) the key physical processes and sources of predictability need to be identified (as they are still not well understood).
3. The realistic initialization of each important climate component is key for skilful predictions.
4. Current perturbation methods (ensemble generation) are not elaborate enough. Perturbations in the initial conditions should correspond to the respective observational uncertainty and focus on the relevant realms (e.g. ocean and cryosphere for decadal, various realms for seasonal).
5. When certain variability patterns are used (e.g., predicting the North Atlantic Oscillation), for consistency these patterns should be derived from the observations as they are likely to be quite different in models.
6. Model biases of different types strongly affect the predictive skill. Hence, it is necessary to continue studying the origin and the impact of model biases. Trying to reduce these biases is most important for all timescales.
7. Regarding the relative benefit of increasing model resolution vs increasing ensemble size, it appears that at this point the latter is a more effective investment (value for money) as it has been demonstrated that in most cases (especially referring to the extratropics) the skill increases monotonically with the ensemble size. Most if not all operational centers have ensemble sizes that are still far from saturating the skill. Instead, increasing model resolution is more costly and even if it leads to the reduction of some model biases, it does

not always reflect on better predictive skill. That said, the quest for models that resolve finer spatial scales is fundamental and must continue.

8. Regarding the so called “signal-to-noise paradox”, it was agreed that this is an “issue” rather than a “paradox”, as the fact that our models still have serious limitations in representing some of the physical processes that underlay predictability (thus having a too weak predictable signal in respect to the chaotic/unpredictable component of the variability) should not surprise us. Clearly, even for the observed variability, only a part of it is forced and predictable.
9. Various examples were discussed indicating that the atmospheric boundary layer in particular (where many parameterizations are active) suffers from a number of biases that need to be reduced, ranging from the polar latitudes to the tropics and from continental areas to the oceans.
10. In order to improve our models we need to better understand the role of certain physical processes for predictability, as well as the causes that give rise to the existing model biases.

Topic 3: Models, errors, and ensemble size

(Facilitators: François Counillon & Noel Keenlyside)
Topic 3 focused on future modelling directions for climate prediction. We discussed four concrete questions.

1. How to treat model bias, and their impact on prediction?

- Short observational period used for historical hindcasts, observational errors and biases, and scale interactions in the climate system all make it a challenge to compute post processed bias corrections. This can lead artificial skill.
- An additional complication is the definition of bias. We need to consider first, second, and higher order errors (i.e., mean, variance, …).
- Biases in models and data are also a challenge for data assimilation approaches. There are however some data assimilation approaches that are more robust to biases (e.g., 4D Var approach is bias aware).
- An alternative method to deal with error is to apply flux correction (or other approaches like anomaly coupling) to correct the model mean biases. However, these approaches are limited and do not necessarily lead to improvements in higher-order moments. Also, they may be challenged in terms of improving non-local connections (e.g., the relation between subsurface and surface temperature).
- Alternative methods to reduce model biases could be interactive ensemble approaches (supermodelling) and regionally enhanced simulations (FESOM) or more computationally efficient models (mixed-precision) models.
- It may be another ten years before global climate models of 1-3 km resolution become used for longer climate and ensemble predictions, although such models already exist for short simulations.

2. Resolution versus ensemble size:

- Large ensemble experiments suggest that predictable signals can only be extracted with a large ensemble.
- At the same time model experiments suggest that high-resolution is critical to capture variability and climatic impacts, and it leads to reduced bias.
- To deal with these two issues it can be useful to investigate blending approaches to use smaller ensemble of high-resolution and a large ensemble of low-resolution predictions.
- Another alternative is to include cheap ensembles – for example using machine learning approaches.

- Ensemble size depends on the questions being addressed. For example, we will also need large ensembles for extreme events. More research on this topic is required.
- Multi-model ensembles can be also used to generate large ensembles, as an alternative to single model ensembles but we need to assess what is the best way to make use of these ensemble".
- Sequential data assimilation can be used to address some ensemble size questions.
- There is greater need to share data from high resolution models and large ensembles, to maximize knowledge gain

3. New observations for frontier models:

- Low resolution data can be biased and not appropriate for tuning frontier models (for example, high-resolution observation can sometimes later prove the existence of features in high resolution models that were thought to be erroneous).
- Uncertainties in observations are needed, and they can account to a certain extent for issues related to mismatch in spatial and temporal resolution.
- Statistics from reanalysis and data assimilation can be used to provide observational uncertainties and identify poor and detrimental data.
- There is a need for observational campaigns and long-term observational programs suitable for assessing high-resolution global climate models.
- There is a need for feedback to observational community on required data:
  - For example through workshops (DG RTD, ESA),
  - Projects involving observationalist and modellers.
- Data assimilation could be used to help identify need for observations.

4. Suggestions for future modelling strategies relevant for climate prediction for Europe:

- We need to prepare ourselves for new computer infrastructure of the future (e.g., hybrid cpu,gpu) that are rapidly evolving and not designed for climate (weather) modelling purposes, we need an appropriately trained workforce and mindset (e.g., to be open to community models), use automated coding, and codes with mixed accuracy calculations (double to single, with loss of bit identical reproducibility).
- In order to include an appropriate level of model diversity, we could identify common components that we agree upon and modulize other more uncertain model components to allow better sharing of codes, and using infrastructure efficiently.
- Need for community infrastructure to share and store data (e.g., JASMIN server in PRIMAVERA), as scientific output has a longer timescale than the production of the data; and mechanisms to enable rerun simulations if more data is required.

Lessons learned and Links built

Collaboration with the Bjerknes Climate Prediction Unit (BCPU): The 2nd Climate modelling workshop has been organised together with the BCPU. BCPU receives funding from the Trond Mohn Foundation under project number BFS2018TMT01. Website: https://bcpu.w.uib.no/

The Bjerknes Climate Prediction Unit aims to provide the best possible predictions of climate in Norway and the North Atlantic region from a season to several years into the future. This is a Bjerknes Centre for Climate Research initiative, lead by the University of Bergen and involving NERSC, NORCE and IMR as partners. It was launched in September 2018 to formalize ~10 years of research at the Bjerknes Centre. The first 5 years receive a funding of 60 mNOK, of which half is provided by the Trond Mohn Foundation and the other half from the involved partners. The initial consortium is composed of 20 prominent scientists from the Bjerknes Centre, with additional strong collaborations from national and international working groups, projects and other initiatives. Our mission is to develop the required theoretical and numerical models to deliver the best possible predictions of climate for the Atlantic-to-Arctic sector and surrounding continents for the next month to years ahead, with the ultimate vision of enhancing climate prediction to a level that it becomes operational and can benefit society.

Progress beyond the state of the art

As explained in the take home messages:

- In the long-term, improvements in understanding of key physical processes are necessary to reduce model error and to improve forecasts.
- Observations are critical to improve models and predictions, as well as to monitor climate. The development of higher resolution models demands new observations that can resolve the simulated phenomena, this requires both observational campaigns and long-term observational programmes, and for greater communication between modellers and observers.
- There are several major challenges facing the development of the next generation of high-resolution climate models: we need to develop strategies to use the new computer infrastructure that are rapidly evolving and not designed for climate (weather) modelling purposes, we need an appropriately trained workforce, we need to adopt community models, while still allowing an appropriate level of model diversity.

Impact

Through these two workshop, we have managed to gather several projects and communities around one table and have shared and transferred knowledge to the climate modelling community.

Contribution to the top level objectives of Blue-Action

This deliverable contributes to the achievement of most of the objectives and specific goals indicated in the Description of the Action, part B, Section 1.1: http://blue-action.eu/index.php?id=4019

- **Objective 1 Improving long range forecast skill for hazardous weather and climate events**
- **Objective 2 Enhancing the predictive capacity beyond seasons in the Arctic and the Northern Hemisphere**
- **Objective 3 Quantifying the impact of recent rapid changes in the Arctic on Northern Hemisphere climate and weather extremes**
- **Objective 4 Improving the description of key processes controlling the impact of the polar amplification of global warming in prediction systems**
- **Objective 6 Reducing and evaluating the uncertainty in prediction systems**
- **Objective 8 Transferring knowledge to a wide range of interested key stakeholders**

Dissemination and exploitation of Blue-Action results

Dissemination activities

Type of dissemination activity	Name of the scientist (institution), title of the presentation, event	Location and full date of the event	Type of Audience	Estimated number of persons reached	Link to Zenodo upload
Organisation of a workshop	UIB, DMI and may other partners	Bergen (NO), 5-7 June 2019	Scientific Community (higher education, Research)	65	https://www.zenodo.org/communities/blue-actionh2020/
Organisation of a workshop	DMI	Copenhagen (DK), 24-26 April 2019	Scientific Community (higher education, Research)	45	https://www.zenodo.org/communities/blue-actionh2020/

Uptake by the targeted audiences

As indicated in the Description of the Action, the audience for this deliverable is the general public (PU) is and is made available to the world via CORDIS.

This is how we are going to ensure the uptake of the deliverables by the targeted audiences:
For the Bergen meeting: we intend to publish a meeting summary based on what we have put together for this deliverable. For the Copenhagen meeting: ASOF has agreed to provide a set of recommendations/best practices on flux calculations, progress and consensus is presently limited in the literature on this topic.

Annex 1: Materials of the Blue-Action and ASOF Workshop 2019 on "Representativeness of ocean observations and Flux calculations"

Presentations

All presentations of the Blue-Action-ASOF meeting can be retrieved here: https://asof.awi.de/outputs/asof-issg-meetings-workshops/copenhagen-april-2019/

From Bering Strait to the Overflows

- Long term variability of Barrow Canyon fluxes and its impact on sub surface warming in the Canada Basin. M. Itoh
- Pacific Water Pathways through the Arctic Ocean to Fram Strait. P. Dodd
- Update on the Atlantic water circulation on the shelf of East Greenland. T. Kanzow
- Submarine melting at the 79 North Glacier, northeast Greenland. O. Huhn
- Diagnosing subinertial variability along the East Greenland Shelf. R. Gelderloos
- Tracing overflow water from the origin in the Nordic Seas to the Greenland-Scotland Ridge. A. Brakstad
- The emergence of the North Icelandic Jet and its evolution from northeast Iceland to Denmark Strait. St. Semper
- Concerns and uncertainties associated with the calculations of fluxes of water masses, heat and salt in the North Icelandic Irminger Current. **S. Jónsson (MFRI, Blue-Action)** https://www.zenodo.org/record/3254770
- How Atlantic heat makes Arctic sea ice retreat. **T. Eldevik (UiB, Blue-Action)** https://zenodo.org/record/3235663 Webrecording: https://jh.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=097da25f-64bc-4aa3-9335-aa3a00cb0b94
- Describing and understanding the annual salinity cycle of the Denmark Strait Overflow. J. Opher
- Evolution of Denmark Strait Overflow Features. M. Almansi
- Frontogenesis and variability in Denmark Strait and its impact on overflow water. R. Pickart
- Circulation and water mass transformation in the Iceland Sea in winter 2015-2016. K. Våge

From the Atlantic to the Arctic Ocean

- Variability of the Atlantic Water inflow to the Nordic Seas via the Faroe-Shetland Channel**. B. Berx (MSS, Blue-Action)** https://www.zenodo.org/communities/blue-actionh2020
- A mechanism for opening of the winter sea ice cover to the north of Svalbard. **C. Herbaut (CNRS, Blue-Action)** https://zenodo.org/record/3066826
- New hydrographic measurements of the upper Arctic Western Eurasian Basin in 2017 reveal fresher mixed

layer and hallower warm layer than 2005 - 2012 climatology. M. Athanase
- A case study: the dynamics of a surface temperature in the Arctic Ocean. Z. Koenig

Representativeness of ocean observations

- To the construction of the Global Ocean Climatologies. **V. Gouretski (Institute of Atmospheric Physics, Beijing, Blue-Action)** https://www.zenodo.org/record/3248820
- Quantifying the impact of subsurface in-situ observations at important Arctic and Nordic Seas gateways on the Arctic Supolar gyre sTateEstimate. **A. Nguyen (University of Texas, Blue-Action)** https://www.zenodo.org/record/3248822 Webrecording: https://jh.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=6c79df9d-470a-4758-a96c-aa3a0084773c
- Combining satellite altimetry and in-situ observations to monitor transports of volume, heat, and salt in the Faroe Current. **B. Hansen (Havstovan, Blue-Action)** https://doi.org/10.5281/zenodo.2669417 Webrecording: https://jh.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=a5018510-c954-4a49-9cff-aa3a00a2e4d4
- MOSAiC: the role of small and (sub) mesoscale processes in observational scales (Remote presentation). B. Rabe
- Report from Bergen Workshop. M. Karcher

Fluxes and Budgets

- An improved estimate of the coupled Arctic energy budget. M. Mayer
- Freshwater fluxes and variability in the Arctic Ocean and subarctic North Atlantic. M. Horn
- Multi-model comparison of Arctic freshwater volume and exports from PRIMAVERA models historical simulations. R.F. Franco
- Arctic gateway transport and sensitivity in the ANHA NEMO configuration. P. Myers
- Attributing the variation of Arctic-midlatitude oceanic transports. Q. Wang
- Increased ocean heat transport towards the Arctic Mediterranean 1993-2016. T. Tsubouchi

Discussing the flux calculations controversy

- Reference values: what changes by changing references values? T. Tsubouchi
- No need for arbitrary reference values? S. Bacon
- Freshwater in the ocean is not a useful parameter in climate research. U. Schauer

Ocean-Sea Ice interaction

- The Barents Sea cooler in a warming ocean. Ø. Skagseth
- The dominant spatial patterns of Barents Sea ice variance and retreat. E. Efstathiou
- Insights from 1-D modelling of winter Arctic sea ice observations: sensitivity studies and snow-ice formation. S. Gani
- Under-ice phytoplankton blooms in the central Arctic Ocean: Insights from the first biogeochemical IAOOS platform drift in 20187. E. Boles

Web recordings

All webrecordings of the presentations can be found here:

https://jh.hosted.panopto.com/Panopto/Pages/Sessions/List.aspx#folderID=%222364b20c-253a-49d2-93ef-aa3900792a92%22

Annex 2: Materials of the Workshop on Climate Prediction in the Atlantic-Arctic sector (2nd EU Climate Modelling Cluster)

Presentations, posters and contributions

All these can be accessed in Zenodo: https://www.zenodo.org/communities/blue-actionh2020/

List of the interventions

Mechanisms giving rise to climate predictability *Chair: Helene Langehaug, NERSC*

Rong Zhang (GFDL, **keynote**) Mechanisms for decadal climate predictability in the Atlantic-Arctic sector

Nour-Eddine Omrani (UiB, BCPU) Understanding the multidecadal Northern Hemisphere climate variably from the perspective of damped Coupled stratosphere/troposphere/Ocean oscillation

Jennifer Mecking (University of Southampton, Blue-Action) Ocean versus Atmosphere in the Eastern North Atlantic Subpolar Gyre Ocean Heat Content

Pablo Ortega (BSC, APPLICATE) A multi-model comparison of the ocean contributions to multidecadal variability in the North Atlantic

Mechanisms giving rise to climate predictability cont. *Chair: Fei Li, NILU*

Shuting Yang (DMI, Blue-Action, EUCP) On the climate variability and the recent abrupt cooling over Subpolar North Atlantic

Jeremy Grist (NOC, Blue-Action, PRIMAVERA) Re-emergence of North Atlantic subsurface ocean temperature anomalies in a seasonal forecast system

Hilla Gerstman (ETH Zurich, Blue-Action) Stratospheric influence on extreme weather events in the North Atlantic basin

Guillaume Gastineau (SU, Blue-Action) Atmospheric response to the observed sea-ice variability: role of continental snow cover and decadal SST variability

Mechanisms giving rise to climate predictability cont. *Chair: Jennifer Mecking, University of Southampton*

Johann Jungclaus (MPI, PRIMAVERA, **invited**) Detecting changes in North Atlantic variability under global warming

Marius Årthun (UiB, BCPU, Blue-Action) The role of Atlantic heat transport in future Arctic winter sea ice loss

Paul Kushner (University of Toronto) Competing Roles of Fast and Slow Climate Responses to Aerosol Forcing in Sahel Precipitation during the Late 20th Century

Challenges to developing climate services *Chair: Tor Eldevik, UiB*

Beatriz Balino (UiB, CORA) Brief overview of the Joint Coordination Office for WCRP Regional Activities

Francisco J. Doblas Reyes (BSC, EUCP, **keynote**) Transitioning climate prediction from research to operations and services

Erik Kolstad (NORCE, Blue-Action, **invited**)

Anne Britt Sandø (Institute of Marine Research, BCPU) Potential applications of climate predictions on different levels in the marine ecosystem

Mette Skern-Mauritzen (Institute of Marine Research) The use of climate predictions to inform fisheries and ecosystem management – an ICES perspective

Panel discussion

Franz Immler, Head of Sector Climate Action, EASME, European Commission

Francisco J. Doblas Reyes, Director of Earth Sciences Department at BSC

Erik Kolstad, senior researcher at Regional Climate & Climate Services group, NORCE, and adjunct professor at Centre for Climate and Energy Transformation, UiB

Mette Skern-Mauritzen, Leader of the Ecosystem Processes research group atHavforskningsinstitutt

Tor Eldevik*, Co-leader of the Bjerknes Climate Prediction Unit and Deputy director of the Bjerknes Centre for Climate Research* panel discussion facilitator

Mechanisms giving rise to predictability cont. *Chair: Stefan Sobolowski, NORCE*

Elisa Manzini (MPI, Blue-Action) Nonlinear Response of the Stratosphere and the North Atlantic-European Climate to Global Warming

Pier Luigi Vidale (University of Reading, PRIMAVERA) Global Climate Modelling at High Resolution in PRIMAVERA/HighResMIP

Dmitry Sein (AWI, PRIMAVERA) Simulating the Arctic climate with the AWI climate models: From global to regional scales

Climate predictability limits

Jon Robson (University of Reading, **invited**) Recent multivariate changes in the North Atlantic climate system, with a focus on 2005–2016

Climate predictability limits cont. *Chair: Ingo Bethke, UiB*

Thomas Jung (AWI, APPLICATE) Advanced prediction in polar regions and beyond (APPLICATE): Recent progress

Iuliia Polkova (Universität Hamburg, Blue-Action) Preconditions for cold air outbreaks and prediction skill

Helene R. Langehaug (NERSC, BCPU, Blue-Action) Assessing poleward propagation of temperature anomalies in decadal hindcast experiments

Juliette Mignot (IPSL, Blue-Action, EUCP) IPSL-EPOC decadal prediction system: an update from the trenches

Daniela Matei (MPI, Blue-Action) Decadal-scale predictive skill of the North Atlantic upper-ocean salt content and its attribution to the initialization of the North Atlantic Ocean Circulation

Climate predictability limits cont. *Chair: Martin King, NORCE*

Rosemary Eade (Met Office, **invited**) Decadal Variability and Trends with a focus on the North Atlantic Oscillation

Panos Athanasiadis (CMCC, Blue-Action, PRIMAVERA) Preliminary title: Decadal prediction of NA Blocking

Francois Counillon (NERSC, BCPU, Blue-Action) The role of model bias for prediction skill and methods to constrain it

Data assimilation for reanalysis and model initialization *Chair: Madlen Kimmritz, NERSC*

Eugenia Kalnay (UMD, **keynote**) Two new ways to improve reanalysis: Use future observations to improve the analyses and forecasts, and minimize reanalysis "jumps" when introducing new observing systems

Steve Penny (University of Maryland, **invited**) Transitioning to strongly coupled data assimilation for Earth system initialization

Benjamin Menetrier (IRIT, **invited**) Localization for ensemble DA: objective diagnostic and efficient application

Patrick Laloyaux (ECMWF, **invited**) Application of coupled data assimilation at ECMWF

Data assimilation for reanalysis and model initialization *Chair: Francine Schevenhoven, UiB*

Yiguo Wang (NERSC, BCPU, Blue-Action) Development of ensemble-based data assimilation techniques for climate prediction

Victor Estella Perez (LOCEAN, Blue-Action) Reconstructions of the AMOC in the historical period using surface data with the IPSL coupled model

Madlen Kimmritz (NERSC; BCPU, Blue-Action) The role of ocean and sea ice for seasonal prediction in the Arctic

Filippa Fransner (UiB, BCPU) Ocean biogeochemical predictions - the role of initial conditions and sources of potential predictability

Posters

Mechanisms

Ramon Fuentes-Franco (SMHI, PRIMAVERA, EUCP) Possible tropical sources of predictability for inter-annual variability of summer precipitation over Northern Sweden and Finland

Hjálmar Hátún (Faroe Marine Research Institute) An inflated subpolar gyre blows life towards the northeastern Atlantic

Valerio Lembo (University of Hamburg, Blue-Action) Prediction of the long-term climate response in a coupled climate model using response theory

J. Oelsmann (presented by Johann Jungclaus) (MPI-Met) AMOC-related SST variations as a driver of the Atlantic Multidecadal Variability in MPI-ESM1.2

Lea Svendsen (UiB, BCCR, BCPU) Pacific contribution to decadal surface temperature trends in the Arctic
Noel Keenlyside (UiB, BCCR, BCPU) Impacts of CGCM bias reduction on the equatorial Atlantic inter-annual variability

Predictability limits

Ingo Bethke (UiB, BCPU, Blue-Action) Improving statistical methods for assessing climate prediction skill

Torben Schmith (DMI, Blue-Action, EUCP) Semi-empirical improvement of seasonal forecasts of European winter temperatures

Fei Li (NILU, BCPU) Subseasonal-to-Seasonal Forecasts with the Norwegian Climate Prediction Model

Bo Christiansen (DMI, Blue-Action, EUCP) The skill of dynamical decadal forecasts with focus on the North Atlantic region
Stefan Sobolowski (NORCE) Investigating drivers of midlatitude circulation biases in climate reanalysis ensembles
Leilane Passos (UiB, BCPU) Interannual to Decadal Predictions of Thermohaline Anomalies and Air-Sea Interaction in the Subpolar North Atlantic and the Nordic Seas

Data assimilation

Sebastien Barthélemy (UiB, BCPU) Hybrid covariance and dual resolution assimilation for high resolution model
Ali Aydogdu (NERSC) Data assimilation using adaptive, non-conservative, moving mesh models

Avneet Singh (BCPU) Optimising cross-covariance update in strongly coupled data assimilation

Data assimilation posters list ctd.
Francine Schevenhoven (BCPU) Efficient algorithms to train supermodels
Julien Brajard (NERSC) Data assimilation as a machine learning tool or in combination with it to emulate a dynamical model from sparse and noisy observations.

Tian Tian (DMI, Blue-Action) The role of Arctic sea ice initialisation in decadal climate prediction: linking the Arctic sea ice loss and the mid-latitude climate

Annex 3: Outcomes of the panel discussion held on 5 June 2019

Panel discussion with: Franz Immler, Head of Sector Climate Action, EASME, European Commission, Francisco J. Doblas Reyes, Director of Earth Sciences Department at BSC, Erik Kolstad, senior researcher at Regional Climate & Climate Services group, NORCE, and adjunct professor at the Centre for Climate and Energy Transformation, UiB, Mette Skern-Mauritzen, Leader of the Ecosystem Processes research group at Havforskningsinstitutt and member of ICES (International Council for the Exploration of the Sea),Tor Eldevik (panel discussion facilitator), Co-leader of the Bjerknes Climate Prediction Unit and Deputy Director of the Bjerknes Centre for Climate Research.

Credits: Chiara Bearzotti (DMI)

Tor Eldevik: "**After listening to all the contributions of today, the first day of the workshop, what can we do better, in your opinion?"**

Franz Immler: "The Commission pushed in the past years for the projects to develop co-design strategies to be incorporated in their structure and workplan, with users being part of the consortia and not just "receivers" of what projects produced. This has been a learning process, but now we see an increase in the demand of climate information and climate services co-design that has resulted from these programs fostering a "supply driven" process. Demand is increasing from sectors such as the insurance and the finance sector and their need to get climate information is growing. Shorter timescales, like seasonal forecast or nowcast, are interesting for most of the users. However, in particular seasonal forecast is still a big challenge for the suppliers. However, during the presentations I learned there are ways of providing skillful predictions. That is where the focus should be: how to produce forecasts on seasonal timescales? "

Mette Skern-Mauritzen: “Scope for use of climate information is increasing, management needs are growing, thus we need to start engaging and ask questions “what is your challenge” and mostly “how can we help you”. People (users) do not know what they need and instead of asking what products they need, we need to ask them about their challenges. Changing the science topics or priorities might be needed in case these do not match the demand, scientists need to be open. And we need to engage better. Two more open questions are: Where can ICES (International Council for the Exploration of the Sea) use climate predictions in their scientific work underlying advice, e.g., in integrated ecosystem assessments? And how and when should a broader audience be invited to the discussion?”

Francisco J. Doblas Reyes: “A question from the audience was posed on "what can we do, do we need to change the priorities of our research?". The answer is no, we don’t need to change our research priorities, but there is something that we definitely need to do: we need to find ways to get engaged, both with scientists working in other domains or time scales and users, but also we need to go to schools and talk to broader audiences, engage with artists, get involved, be curious and provide inputs. “

Erik Kolstad: “There is still the need to do modelling, improve modelling and the skill of the forecast. We can nevertheless change a little bit our way of working. For instance StormGeo has had an amazing success in presenting weather data. For example, they created maps of projected insurance payments linked to weather where the risks are visualised in dollars. This is an example on how we need to change the way we work but still do modelling. We need to realise that companies do not care about the skill of NAO but they care about what they can gain when using our models.”

Take home messages:

The potential for useful and needed societal and commercial applications based on climate prediction is well established. However, realising the same potential partly remains a challenge due to the need for better (and simply more) co-design, co-production and co-development of relevant climate information with stakeholders, and due to predictive skill itself still being a research frontier.

Tor Eldevik: “What do we do very well?”

Franz Immler: “Science triggered the political discussions that ended in the definition of the Paris Agreement. This was a huge success even if the agreement is still only on paper. Scientists have learned how to inform people at various levels, for instance policy makers. The next challenge is to work with business audiences, and to inform business players.”

Mette Skern-Mauritzen: “We have become game changers in moving around time scales for management support, in the decision making.”

Francisco J. Doblas Reyes: "We provided basis for the awareness of climate change. Currently children demonstrate in the world because they are scared about the future, we need to highlight the work done on climate science. No children will demonstrate for seasonal forecast, but there is a narrative missing for helping us in communicating what we do and increase awareness."

Erik Kolstad: "In Norway there is a person in the strawberry business that is taking seasonal forecast used are from web pages, not from official reliable sources. We need to tell such people that we have something they can use. True, there is a missing narrative."

Take home messages:

Climate research has unprecedented credibility and public attention when it comes to the general context of climate change. We need to develop narratives to achieve a similar level of awareness and credibility in the outside world the more immediate and thus more applicable climate predictions. This will accelerate the co-development of much needed climate services.

Questions from the audience

Q1, Juliette Mignot (CNRS): On the co-producer concept presented by Erik Kolstad, concretely it is difficult for me to find co-producers, I have a collaboration with Senegal, mandated by the French government, I am involved in capacity building measure in this country for setting up climate services for this country, but it is still difficult to find co-producers in this context. Any suggestion? "

Q2, Nour-Eddine Omrani (UiB)**: "**The dialogue with users can be efficient if there are *"mediators"/line of people* able to translate science into a service like in the examples provided by Mette. This is not necessarily the scientists involved in the research."

R, Mette Skern-Mauritzen: "Social scientists should be involved for facilitating dialogue and communication and act as mediators."

R, Franz Immler: "Support interdisciplinary work, train scientists in communication, train those working in this interface position in communication. Raise awareness to plan more training. Support decision makers in taking their decisions by factoring in the "Nature" factor."

Q3, Jon Robson: " It was mentioned we are missing a *"narrative"*, but what kind of narrative should we have in mind?"

R, Francisco J. Doblas Reyes: "There is no single "narrative", we need to find the narrative in response to the demand, the narrative does not have to come from us, but from our answers to questions posed by the users".

Q5, Pier Luigi Vidale (UREAD): "Working with companies focal point is the data they can trust and rely upon. Improving the model, keeping the model up to date, this is also implying a lot of work. One should also be aware that there are companies who will turn out data into 'science-based' products without themselves being particularly concerned by or committed to their actual skill or usefulness".

Q6, Jan Erik Stiansen (IMR):" How can we all talk the same language? Experience I made with economists and an IMR group talking to each other in a project but it took to us two years to get to speak the same language"
R, Erik Kolstad: "Education is the key, training, capacity building, there will be in October a school on co-production of climate service[1], this is a good chance".
R, Francisco J. Doblas Reyes: " We need to have good translators and intermediaries who sit in between the lanes. Unfortunately, they do not exist and this school Erik mentioned could be a chance to create these professionals".

Q7 Iuliia Polkova (UHAM): **"**What is the strategy in building trust in long term perspective? Do we need to create a climate service department inside universities and in research institutions?"
R, Erik Kolstad: "The trust can be gained through boundary work. The point is to train these people who work as civil servants/decision-makers in boundary organisations".
R, Mette Skern-Mauritzen: "Complexity can be overwhelming. We need to find local champions who change the game through collaborations and in engaging in a variety of conversations".
R, Franz Immler: "Institutions like met offices need to provide climate information that can be trusted for disaster reduction. The sale services of the met offices can sell these services and information. There is also room for private businesses here to grow and create new jobs and growth".

Take home messages from the Q&A session:

One should on the one hand not underestimate the scientists' will to make their research-based climate predictions relevant and practically accessible interacting with the interested public. On the other hand, there is a rising awareness that "an honest broker" – a specialist in understanding and communicating both sides – would be most beneficial for realising the potential of climate prediction in the public domain.

Scientists working on climate prediction often find it challenging to engage with stakeholder partners, because of language and their different viewpoints. The development of climate services can close this gap between scientists and stakeholders through training of new work forces. There is room for both public and private sectors to work together in this field.

[1] Organised by Erik Kolstad and Scott Bremer at the University of Bergen. The web page for the school is found here: https://www.uib.no/en/svt/126835/co-production-climate-adaptation-research